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2D CONGRESS, *1st Session.* SENATE. Ex. Doc. 41, Part 1.

A REPORT

ON

IRRIGATION

AND

THE CULTIVATION OF THE SOIL THEREBY,

WITH

PHYSICAL DATA, CONDITIONS, AND PROGRESS WITHIN
THE UNITED STATES FOR 1891,

ACCOMPANIED BY

MAPS, ILLUSTRATIONS, AND PAPERS.

BY

RICHARD J. HINTON,
Special Agent in Charge,
OFFICE OF IRRIGATION INQUIRY, DEPARTMENT OF AGRICULTURE.

PART I.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1892.

LETTER

FROM

THE SECRETARY OF AGRICULTURE,

TRANSMITTING

The final report of the artesian and underflow investigation and of the irrigation inquiry.

FEBRUARY 4, 1892.—Referred to the Committee on Printing.
FEBRUARY 17, 1892.—Ordered to be printed.

DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY,
Washington, D. C., February 4, 1892.

SIR: I have the honor to transmit herewith the final report of the artesian and underflow investigation and of the irrigation inquiry, as conducted under my direction in pursuance of authority conferred by act of Congress approved April 4, 1890, and an act approved September 30, 1890, and an act approved March 3, 1891, and to state that it was fully completed and deposited in accordance with the terms and conditions of the last-mentioned act.

I have the honor to remain, yours respectfully,

J. M. RUSK,
Secretary.

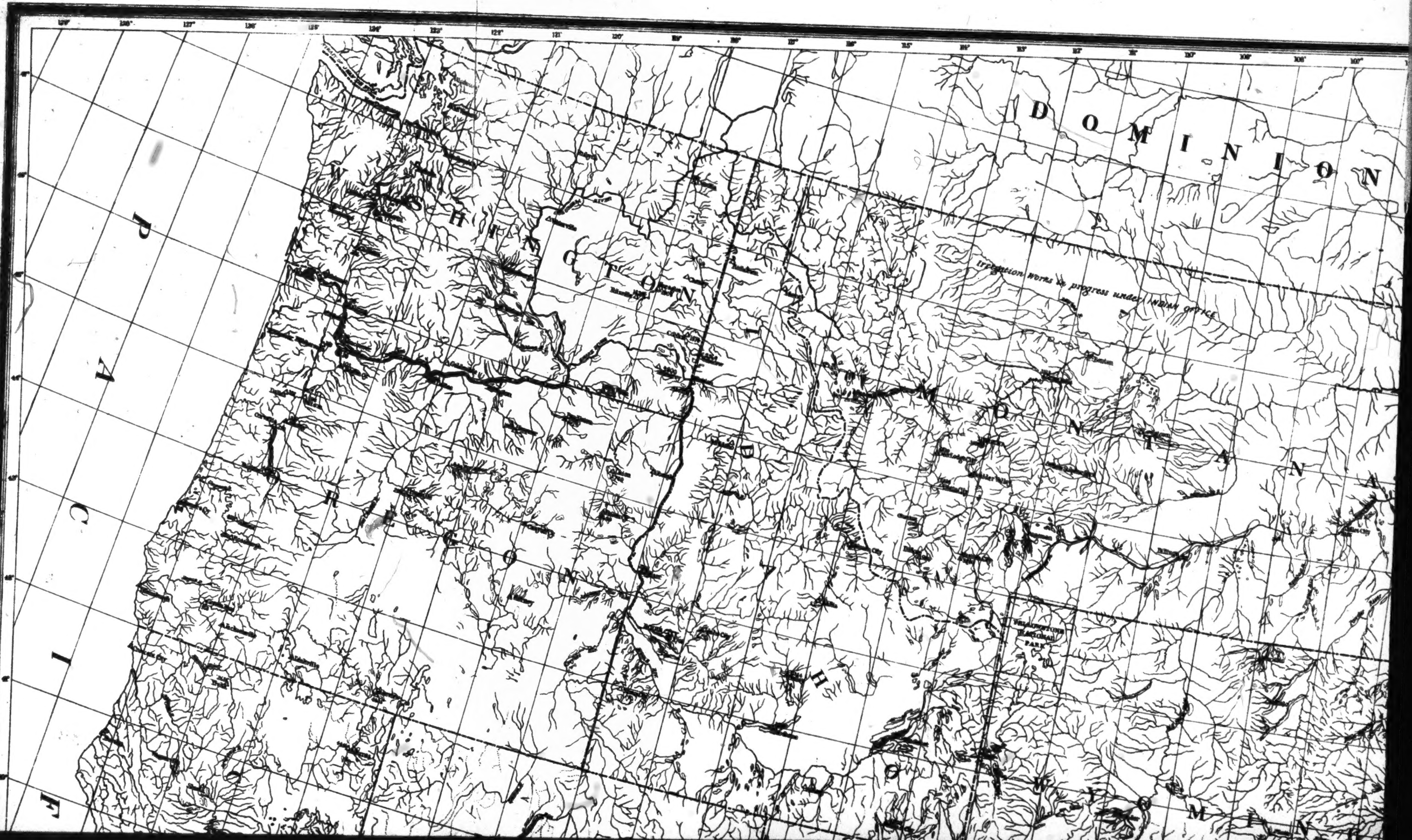
The PRESIDENT OF THE SENATE.

TABLE OF CONTENTS.

Page.
Letter of transmittal, Secretary of Agriculture 3
Preliminary 5–7
  Work on the Great Plains and the results 7–9
  Water conservation and management 9
  State supervision of irrigation and works 10–12
  Growth of reclamation for 1891 12–18
  Art of irrigation and American success 18–20
  Work of American engineers 19–20
  Irrigation legislation 20–27
  Municipal control of irrigation water and works 27–29
  Opposition to the system 29–34
  Fruit culture by irrigation 34–36
  Arid climatology 37–41
  Aëration of water and irrigation 41–45
  Need of drainage 45–46
  River silt and its value 46–47
  Influence of light and heat on vegetation 48–49
  Alkali and irrigation 49–54
Physical conditions and progress of irrigation 55
  Irrigation in States and Territories 57
    Arizona 57–80
    California 81–131
    Colorado 132–164
    Idaho 165–182
    Montana 183–197
    New Mexico 198–227
    Nevada 228–237
    Oregon 238–245
    Utah 246–265
    Washington 266–275
    Wyoming 276–287
    The Great Plains—Kansas, Nebraska, the North and South Dakotas, Texas 288–298
Papers accompanying the report of the Office of Irrigation Inquiry:
  Preliminary report on the possibilities of the reclamation of arid regions of Kansas and Colorado by utilizing the underground waters. Howard Miller, Ph. D 301–306
  Methods of applying water to land as practiced in the central portions of California. C. E. Grunsky, C. E 307–322
  Cultivation of the soil by means of irrigation in some of the Southern States 323–349
  Agricultural hydraulics. From the French of M. J. Charpentier de Cossigny 351–370
  Irrigation by artesian wells in Algiers 372–377
  Facts and conditions relating to irrigation in various countries. Richard J. Hinton 379–432
  Extent and importance of ancient water supply and irrigation works. Frederick S. Gipps, C. E., Sydney, New South Wales 434–438

TABLE OF MAPS AND ILLUSTRATIONS.

Map illustrating progress of irrigation reclamation .... at title.
Physical conditions and progress of irrigation ....
Rio Gila Valley, unreclaimed lands 57
Mohawk Valley, looking southeast 65
Orange orchard, Los Angeles, Cal 81
Turlock and Modesto Dam, Stanislaus County, Cal. 100
Modern cement ditch, near Redlands, Cal 107
"Zanja," or old-style ditch, near Redlands, Cal 111
Cement hydrant and flume, near Redlands, Cal 119
Irrigated kitchen garden and orchard, Tulare, Cal 122
No. 1 Flume, Colorado Canal, Arkansas Valley, Colo 132
Diagram, water strata, San Luis Valley, Colo 135
Map of Greeley canals, Colorado 138
View of Greeley, Colo., 1870 141
Garden by irrigation, Greeley, 1890 145
Pumping plant at Greeley 146
Canals of Otero County, Colo 147
Plan of the Big Sandy underflow 150
Diagram representing canal wear 155
Artesian Basin, map of San Luis Valley 153
Irrigation by seepage 155
Snake River Canals 167
Map of southern Idaho 169
Rocky Cañon Trestle and Flume, Montana (Gallatin Valley) 190
Irrigation by checks, Montana, (Gallatin Valley) 192
Rio Pecos, near Roswell, N. Mex 198
Irrigated market garden, in Santa Fe, N. Mex 206
Raton table land reservoirs, Santa Fe, N. Mex 209
Irrigated orchard near Roswell, N. Mex 221
Rock cut on curve, Pioneer Canal, Texas 222
Residence and orchard near Eddy, N. Mex 224
Sage brush and alfalfa, Wadsworth, Nev 230
Underflow works, Emigration Cañon, Utah 250
Irrigation map of Wyoming 261
Railroad map, showing underflow region and wells 301
Plans and diagrams illustrating irrigation methods in central California. C. E. Grunsky, C. E. 18 plates, from pages 307–322
Box irrigation in Piedham Orchard, Texas 347
Two-year-old irrigated tree in Piedham Orchard, Texas 348
Spike channels 356
Phreatic waters in Desert of Sahara 373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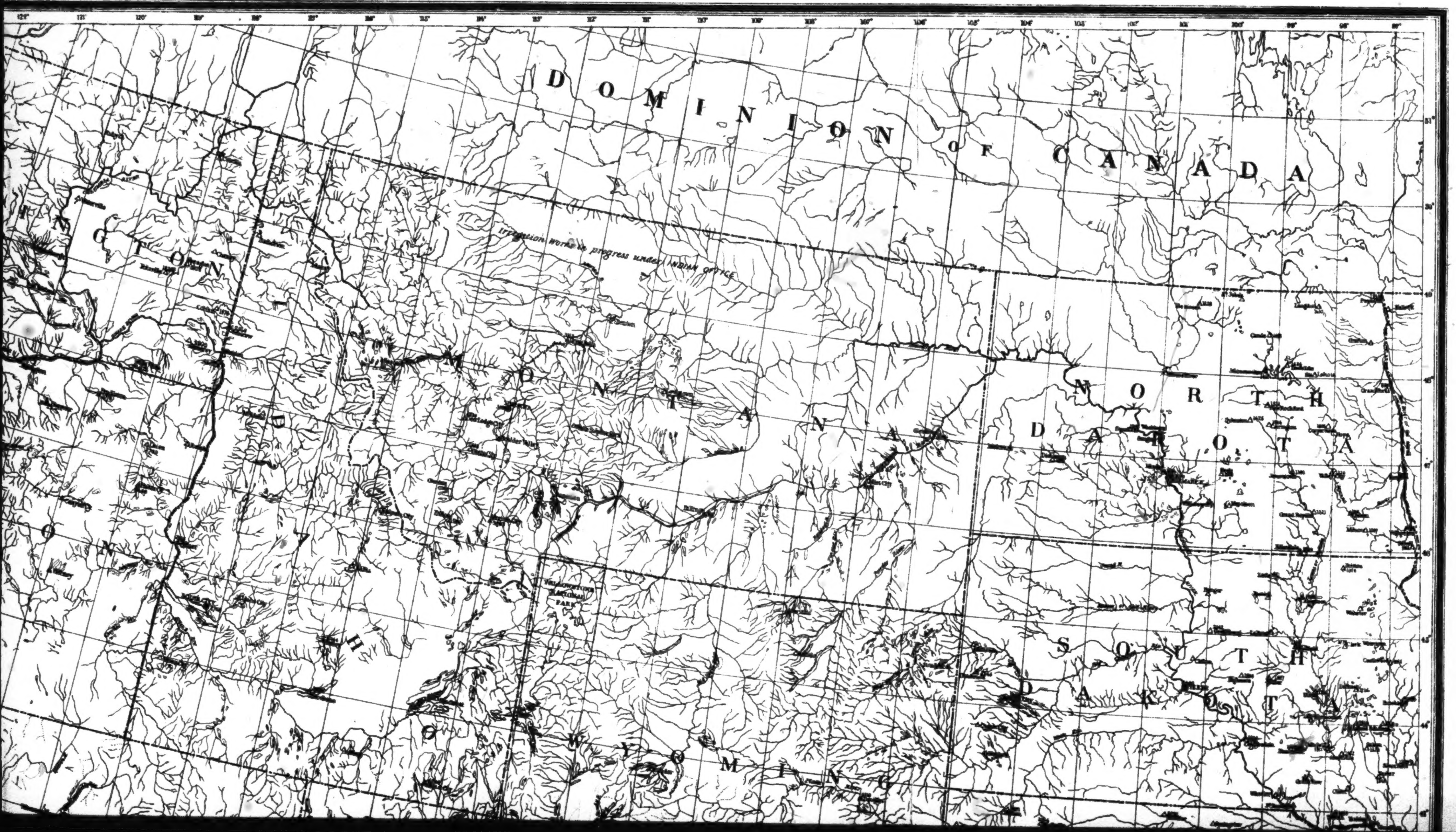
WYOMING
Irrigation works in progress under Indian Office
YELLOWSTONE NATIONAL PARK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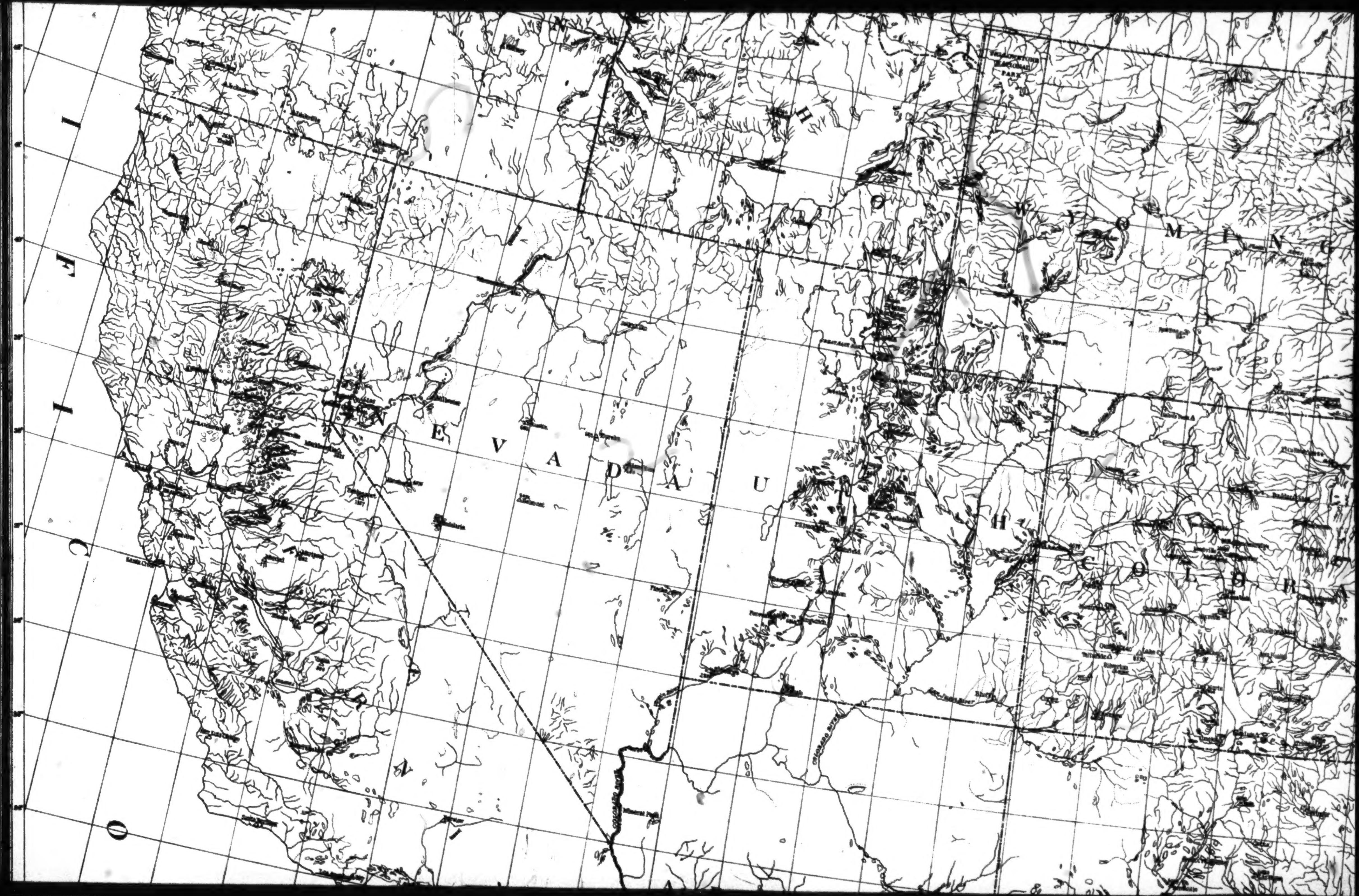
NEVADA
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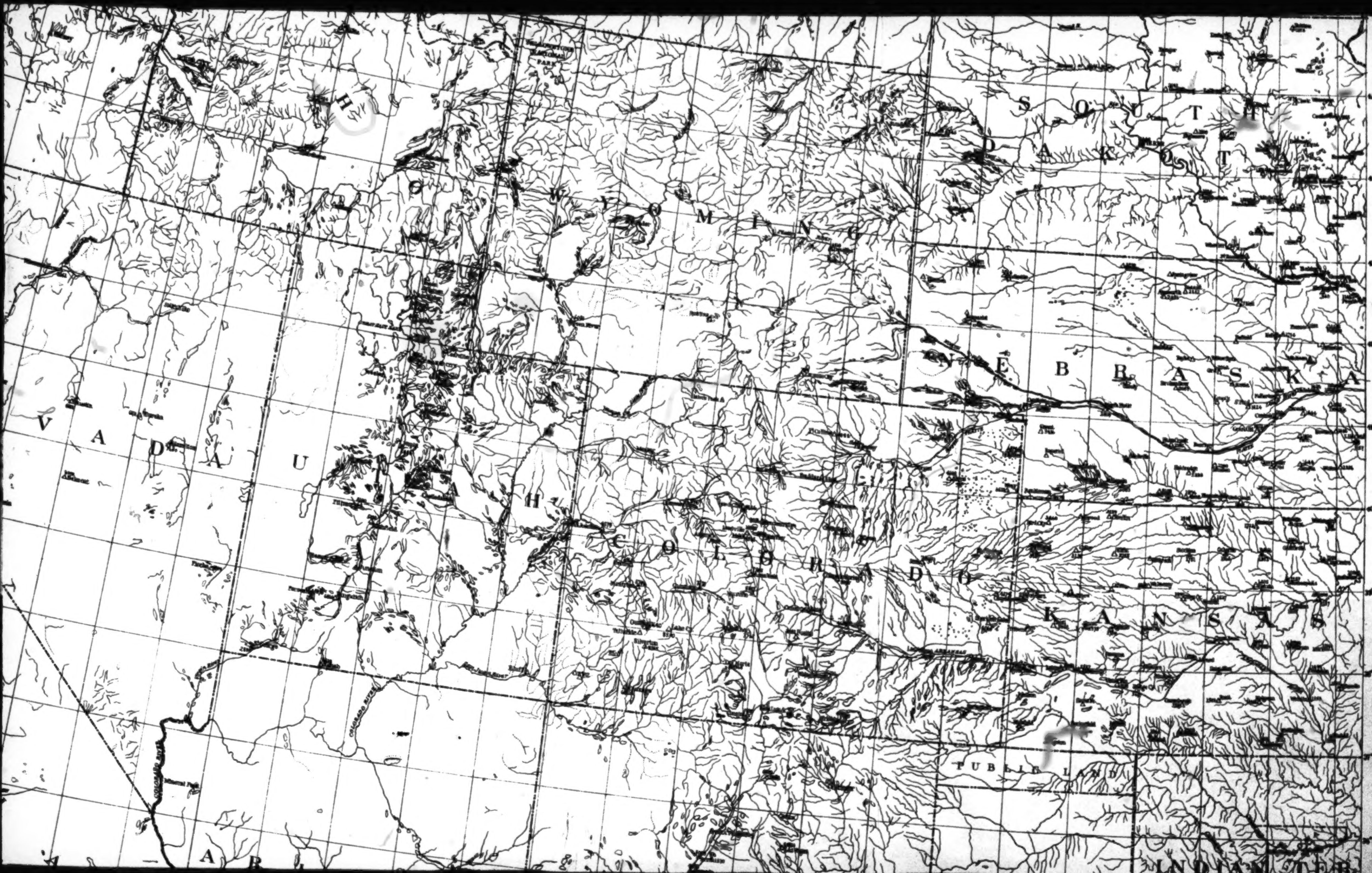
COLORADO RIVER



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WYOMING
YELLOWSTONE NATIONAL PARK
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N E B R A S K A
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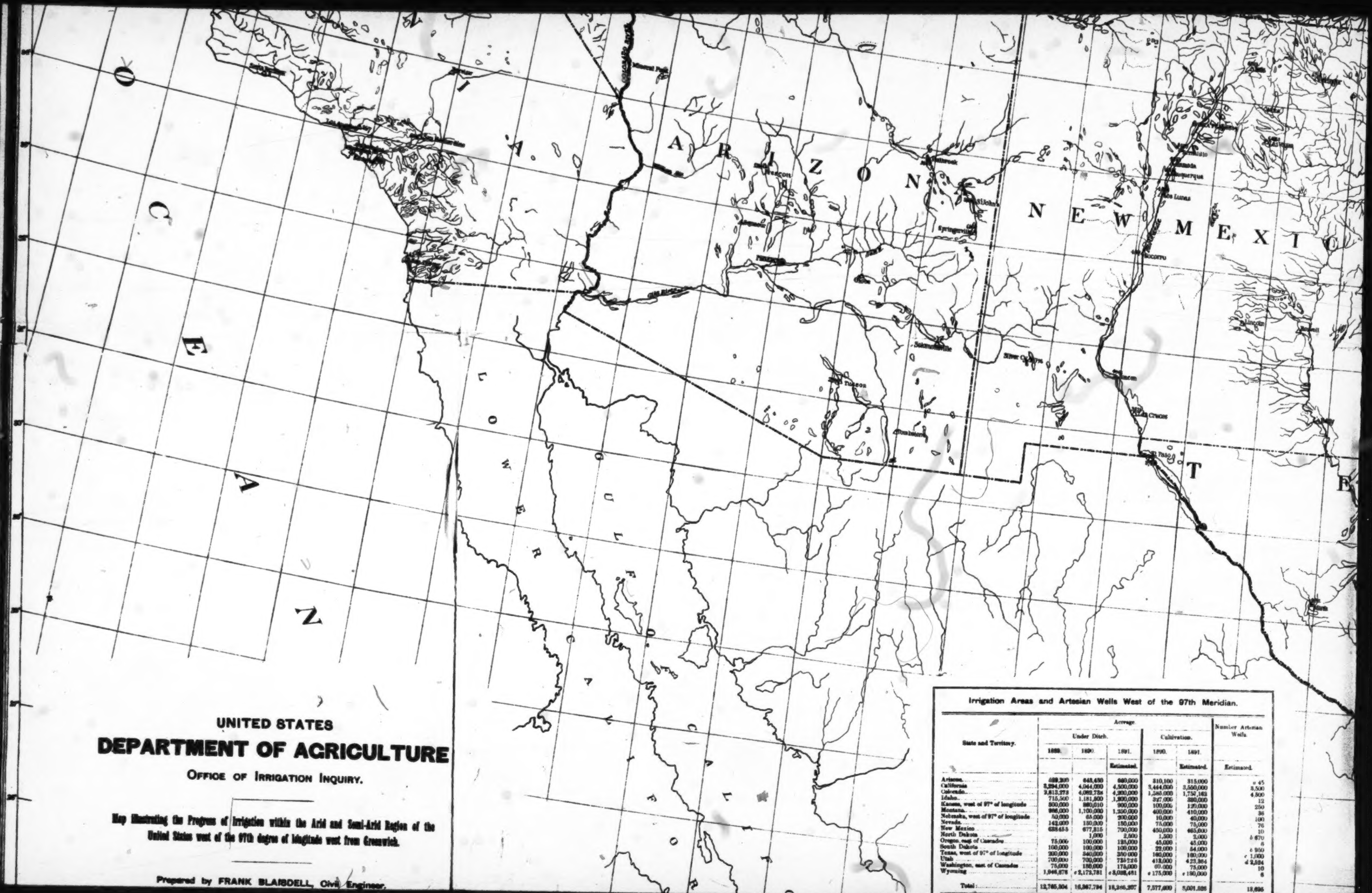
C O L O R A D O
K A N S A S
PUBLIC LAND
INDIAN TER.
COLORADO RIVER
A R I



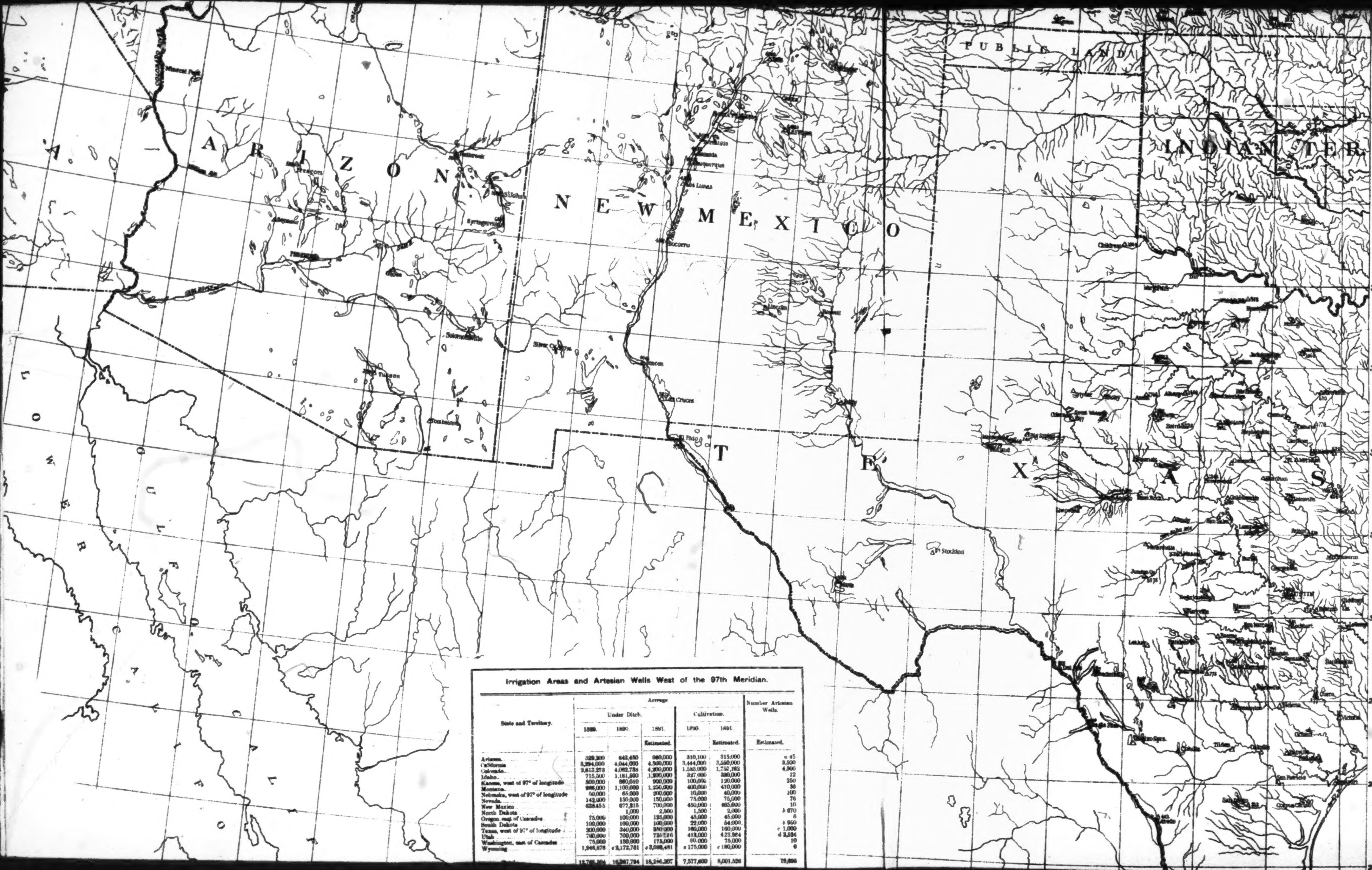
UNITED STATES
DEPARTMENT OF AGRICULTURE
OFFICE OF IRRIGATION INQUIRY.

Map Illustrating the Progress of Irrigation within the Arid and Semi-Arid Region of the United States west of the 97th degree of longitude west from Greenwich.

Prepared by FRANK BLAISDELL, Civil Engineer.

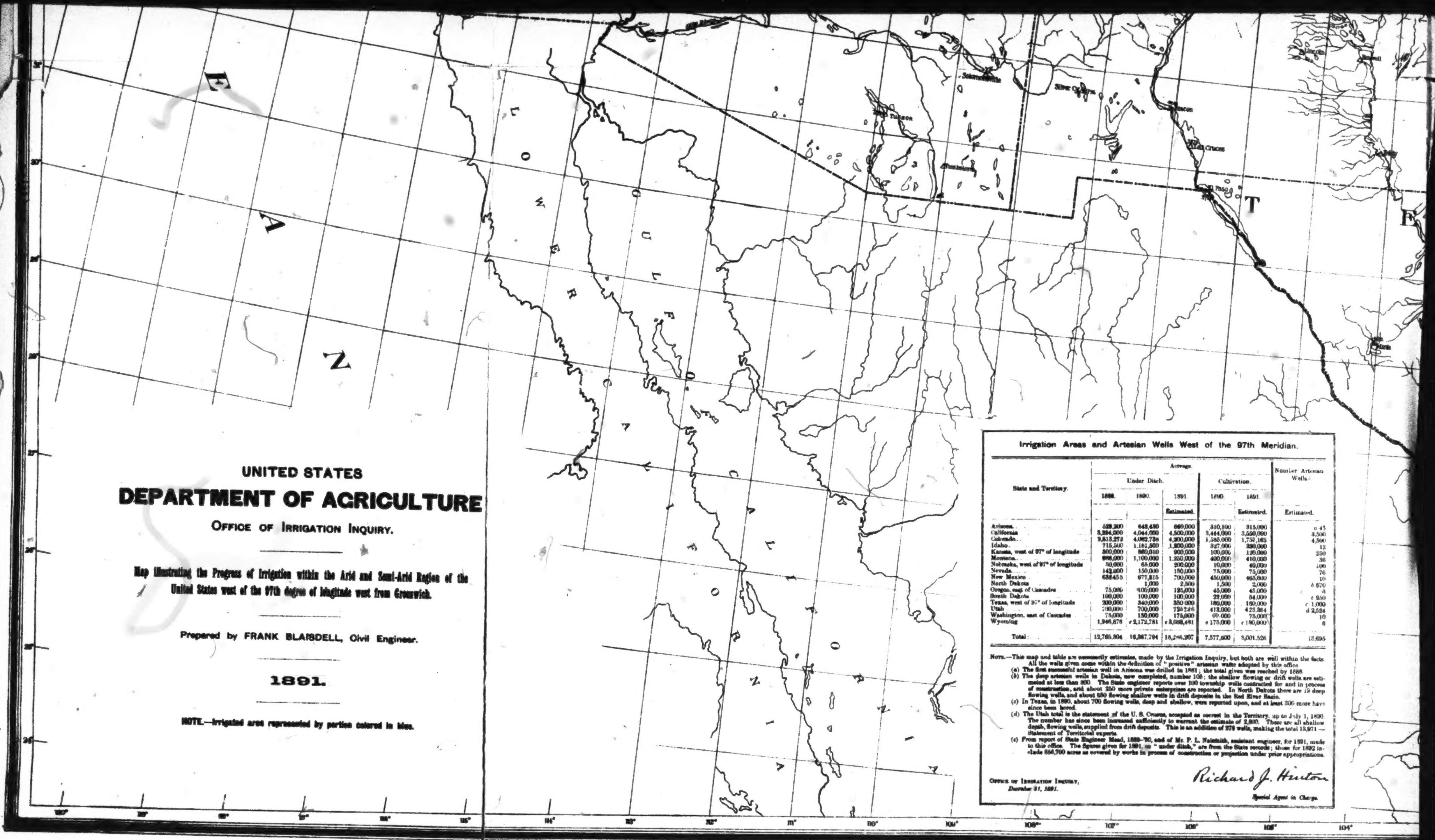
Irrigation Areas and Artesian Wells West of the 97th Meridian.

State and Territory.	Acreage.					Number Artesian Wells.
	Under Ditch.			Cultivation.		
	1889.	1890.	1891.	1890.	1891.	
			Estimated.		Estimated.	Estimated.
Arizona	489,200	643,450	660,000	310,100	315,000	a 45
California	3,294,000	4,044,000	4,500,000	3,444,000	3,550,000	3,500
Colorado	2,813,273	4,082,786	4,200,000	1,585,000	1,757,162	4,800
Idaho	715,500	1,181,800	1,800,000	327,006	380,000	12
Kansas, west of 97° of longitude	500,000	880,010	900,000	100,006	120,000	250
Montana	966,000	1,100,000	1,250,000	400,000	410,000	36
Nebraska, west of 97° of longitude	50,000	65,000	200,000	10,000	40,000	100
Nevada	142,000	150,000	150,000	75,000	75,000	76
New Mexico	638455	677,815	700,000	450,000	465,000	10
North Dakota		1,000	2,500	1,500	2,000	b 670
Oregon, east of Cascades	75,006	100,000	125,000	45,000	45,000	6
South Dakota	100,000	100,000	100,000	22,000	54,000	c 950
Texas, west of 97° of longitude	200,000	340,000	350 000	160,000	160,000	c 1,000
Utah	700,000	700,000	735226	412,000	423,364	d 2,524
Washington, east of Cascades	75,000	150,000	175,000	60.000	75,000	10
Wyoming	1,946,878	e 2,172,781	e 3,008,491	e 175,000	e 180,000	6
Total	12,765,804	16,367,794	18,266,207	7,577,600	8,001,526	13,696


ARIZONA
NEW MEXICO
TEXAS
INDIAN TER
PUBLIC LAND
LOWER CALIFORNIA
GULF OF CALIFORNIA
Colorado River
Prescott
Phoenix
Tucson
Tombstone
Solomonville
Silver City
St Johns
Springerville
Albuquerque
Los Lunas
Socorro
Las Cruces
El Paso
Ft Stockton
Tilden
Corpus Christi
37°
36°
35°
34°
33°
32°
31°
30°
29°
28°
27°

Irrigation Areas and Artesian Wells West of the 97th Meridian.

State and Territory.	Acreage					Number Artesian Wells.
	Under Ditch.			Cultivation.		
	1889.	1890.	1891.	1890.	1891.	
			Estimated.		Estimated.	Estimated.
Arizona	529,300	648,450	660,000	310,100	315,000	a 45
California	3,294,000	4,044,000	4,500,000	3,444,000	3,550,000	3,500
Colorado	2,813,278	4,082,788	4,200,000	1,585,000	1,757,162	4,800
Idaho	715,500	1,181,600	1,200,000	327,000	330,000	12
Kansas, west of 97° of longitude	500,000	880,010	900,000	100,000	120,000	250
Montana	986,000	1,100,000	1,250,000	400,000	410,000	36
Nebraska, west of 97° of longitude	50,000	65,000	200,000	10,000	40,000	100
Nevada	142,000	150,000	150,000	75,000	75,000	76
New Mexico	628455	677,815	700,000	450,000	465,000	10
North Dakota		1,000	2,500	1,500	2,000	b 670
Oregon, east of Cascades	75,000	100,000	125,000	45,000	45,000	6
South Dakota	100,000	100,000	100,000	22,000	54,000	c 950
Texas, west of 97° of longitude	200,000	340,000	350,000	160,000	160,000	c 1,000
Utah	700,000	700,000	725,726	413,000	423,364	d 2,524
Washington, east of Cascades	75,000	150,000	175,000	60,000	75,000	10
Wyoming	1,946,878	c 2,172,781	c 3,098,451	c 175,000	c 180,000	6
Total	12,795,204	16,267,794	18,286,307	7,577,600	8,001,526	13,096



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Prepared by FRANK BLAISDELL, Civil Engineer.

1891.

NOTE.—Irrigated area represented by portion colored in blue.

Irrigation Areas and Artesian Wells West of the 97th Meridian.

State and Territory.	Acreage. Under Ditch. 1889.	Under Ditch. 1890.	Under Ditch. 1891. Estimated.	Cultivation. 1890.	Cultivation. 1891. Estimated.	Number Artesian Wells. Estimated.
Arizona	529,300	648,480	660,000	310,100	315,000	a 45
California	3,294,000	4,044,000	4,500,000	3,444,000	3,550,000	3,500
Colorado	2,813,273	4,082,728	4,200,000	1,585,000	1,757,162	4,500
Idaho	715,500	1,181,500	1,300,000	327,000	330,000	12
Kansas, west of 97° of longitude	500,000	860,010	900,000	100,006	120,000	250
Montana	966,000	1,100,000	1,250,000	400,000	410,000	36
Nebraska, west of 97° of longitude	50,000	68,000	200,000	10,000	40,000	100
Nevada	142,000	150,000	150,000	75,000	75,000	76
New Mexico	638455	677,315	700,000	450,000	465,000	10
North Dakota		1,000	2,500	1,500	2,000	b 670
Oregon, east of Cascades	75,000	100,000	125,000	45,000	45,000	6
South Dakota	100,000	100,000	100,000	22,000	54,000	b 950
Texas, west of 97° of longitude	200,000	340,000	350 000	160,000	160,000	c 1,000
Utah	700,000	700,000	725 226	412,000	423,364	d 2,524
Washington, east of Cascades	75,000	150,000	175,000	60.000	75,000	10
Wyoming	1,946,878	e 2,172,781	e 3,068,491	e 175,000	e 180,000	6
Total	12,765,304	16,367,794	18,286,207	7,577,600	8,001,526	13,695

NOTE.—This map and table are necessarily estimates, made by the Irrigation Inquiry, but both are well within the facts. All the wells given come within the definition of "positive" artesian water adopted by this office

(a) The first successful artesian well in Arizona was drilled in 1881; the total given was reached by 1888

(b) The deep artesian wells in Dakota, now completed, number 105; the shallow flowing or drift wells are estimated at less than 800. The State engineer reports over 100 township wells contracted for and in process of construction, and about 250 more private enterprises are reported. In North Dakota there are 19 deep flowing wells, and about 650 flowing shallow wells in drift deposits in the Red River Basin.

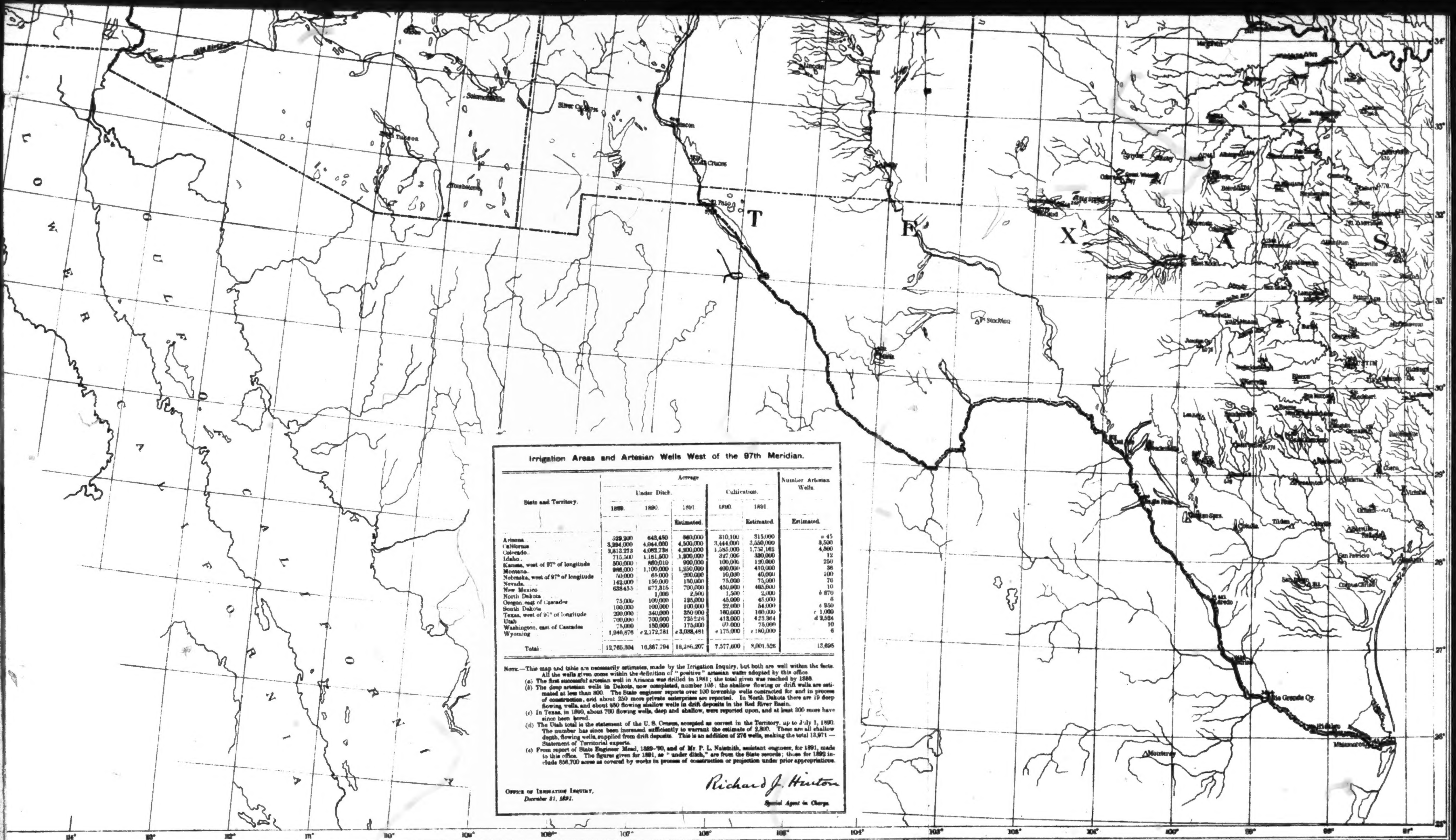
(c) In Texas, in 1890, about 700 flowing wells, deep and shallow, were reported upon, and at least 300 more have since been bored.

(d) The Utah total is the statement of the U. S. Census, accepted as correct in the Territory, up to July 1, 1890. The number has since been increased sufficiently to warrant the estimate of 2,800. These are all shallow depth, flowing wells, supplied from drift deposits. This is an addition of 276 wells, making the total 13,971 — Statement of Territorial experts.

(e) From report of State Engineer Mead, 1889–'90, and of Mr. P. L. Naismith, assistant engineer, for 1891, made to this office. The figures given for 1891, as "under ditch," are from the State records; those for 1892 include 856,700 acres as covered by works in process of construction or projection under prior appropriations.

OFFICE OF IRRIGATION INQUIRY,
December 31, 1891.

Richard J. Hinton
Special Agent in Charge.



L O W E R
C A L I F O R N I A
G U L F
O F
C A L I F O R N I A
T E X A S
Solomonville
Silver City
Tucson
Tombstone
Lincoln
Las Cruces
El Paso
Ft Stockton
Del Rio
Eagle Pass
Laredo
Rio Grande Cy.
Monterey
Matamoros
San Patricio
Corpus Christi
Victoria
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97°

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Colorado	2,813,273	4,082,738	4,300,000	1,585,000	1,757,162	4,800
Idaho	715,500	1,161,500	1,200,000	327,000	330,000	12
Kansas, west of 97° of longitude	500,000	860,010	900,000	100,000	120,000	250
Montana	998,000	1,100,000	1,250,000	400,000	410,000	38
Nebraska, west of 97° of longitude	50,000	65,000	200,000	10,000	40,000	100
Nevada	142,000	150,000	150,000	75,000	75,000	76
New Mexico	638455	677,315	700,000	450,000	465,000	10
North Dakota		1,000	2,500	1,500	2,000	b 670
Oregon, east of Cascades	75,000	100,000	125,000	45,000	45,000	6
South Dakota	100,000	100,000	100,000	22,000	54,000	c 950
Texas, west of 97° of longitude	200,000	340,000	350,000	160,000	160,000	c 1,000
Utah	700,000	700,000	735,226	413,000	423,364	d 2,524
Washington, east of Cascades	78,000	150,000	175,000	80,000	75,000	10
Wyoming	1,946,876	e 2,172,781	e 3,088,481	e 175,000	e 180,000	6
Total	12,765,304	16,367,794	18,286,207	7,577,600	8,001,526	13,695

NOTE.—This map and table are necessarily estimates, made by the Irrigation Inquiry, but both are well within the facts. All the wells given come within the definition of "positive" artesian water adopted by this office.

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OFFICE OF IRRIGATION INQUIRY,
December 31, 1891.

Richard J. Hinton
Special Agent in Charge.

Sackett & Wilhelms Lithographing Co. New York

A REPORT ON IRRIGATION, AND THE CULTIVATION OF THE SOIL THEREBY.

INTRODUCTION.

During the past year, under the direction of the Secretary of Agriculture, the office of irrigation inquiry has endeavored to obtain as comprehensive a view of the conditions of "irrigation, and the cultivation of the soil thereby," as the means appropriated would allow. In the work of the office itself an endeavor was made to systematize the mass of information, data, reports, and papers at its command. That this work has not been entirely completed is due to the pressure of other duties. The increasing correspondence has borne heavily upon the small force employed. This correspondence shows the rapidly growing interest and attention that is being aroused by the whole subject of water management in connection with agriculture. A steady demand has been made for the reports published in relation to the work of the office. This demand has been so great that it has been impossible, with the limited editions issued, to respond to one in fifty of the requests made for the Progress Report of 1891 and that of the report on artesian wells made in 1890. Of the latter report Congress ordered printed its usual edition of 1,734 copies. The Department, for official use, purchased 100 copies, which is all that were at its disposal. As an illustration of the value accorded to this report, it may be stated that dealers in Government publications have been holding a few copies that they obtained at the rate of $2.50 each. Of the Progress Report, Parts I and II, in addition to the ordinary Congressional edition, the Department purchased from the Public Printer 1,500 copies. This number has long since been exhausted, and there are a large number of names on file in the office as evidence of the requests made for the copies of these two reports. Many of these requests are from distinguished foreign engineers and experts, Government officials, and librarians.

During the year past this office has sent out several thousand circulars for the purpose of obtaining the latest data, the responses to which have been more than usually numerous. In face of the fact that requests of a similar character have been circulated by several bureaus and officers belonging to another department, the responses received by the office of irrigation inquiry were gratifying in number and character.

Early in the year it became evident that the work of the inquiry, to be of full value, must be personally directed in the field. It was decided by the Secretary that the special agent in charge, accompanied by an assistant, should visit the several States and the areas within them in which irrigation works are in operation and progress. This conclusion was reached upon the conviction that the work would be more thoroughly accomplished in this wise than by the employment of local agents over whom only a distant and insufficient supervision could be had. As a result of this determination, the special agent left Washington early in May and returned the latter part of July. During the eleven weeks of that absence himself and assistant, traveled by rail about 14,000 miles and by private conveyance some 1,500 more, visiting the most important irrigation centers and districts in the States of Kansas, Colorado, Texas (west of 97°), California, Nevada, Oregon, Washington, and Idaho, as also the Territories of Oklahoma, New Mexico, Arizona, and Utah. While on this journey some forty irrigation districts and centers were visited and inspected; the plans, reports, and maps, etc., of leading organizations were obtained, and the testimony of about 300 persons actively interested in the organization and management of irrigation enterprises was obtained. This testimony, condensed and summarized, is presented in this report.

One of the most notable instances of the past year has been the interest aroused in this subject in sections of the Union that are most largely affected by heavy precipitation and constant humidity. From the South, for example, there has been received a large amount of information on the subject, illustrating the fact that in such States as Louisiana, Alabama, and Texas, the semi-tropical heat of the summer, with its attendant evaporation, tends rapidly to produce drought in the growing season, and as a consequence thereof materially affects the security of the important commercial crops which are grown in our Gulf States. The irrigation problem in Florida gives evidence of being a very interesting one, especially in the eastern part thereof, where artesian water by means of wells can unquestionably be utilized to make secure the orange orchards and vegetable gardens whose productions form so valuable an industry in that State. The evidence and information which has been sent to this office from these and other States has been carefully collated and arranged and is herewith presented. More recently a number of inquiries have been received from the New England States. Another inquiry consists of systematic observations made under the direction of Mr. Howard Miller, special agent of the Department and this office, as to the volume of water, its rise and fall, that may be found and recorded at stated periods of each day in a series of railroad wells, lying along the Kansas branch of the Union Pacific Railway west of Wa Keeney, Kans. The object of these observations, which it has been expected may be conducted through a period long enough to make reasonably sure of the conditions affecting the inlet of the water into the wells, is to ascertain the extent of phreatic draining in the region covered by the observations. It is the principal portion of the area in which what the geologists term the "rivers of the plains" take their rise. The railroad along which the wells are directed passes across a section of the great plains in which the head waters of the Republican and Solomon rivers, the principal branches of the Kansas, make their first appearance on the surface. At moderate depths below the surface, though not always to a regular degree, a gravel stratum is found saturated with drainage waters. In most instances the wells under observation terminate their shafts in this gravel stratum. It will be a matter of great value to be able to ascertain the ebb and flow, if any such exist, of this drainage or phreatic supply.

Mr. Howard Miller's first report, which forms part of the present one, will be examined with interest. Another paper of very considerable technical value is that of Mr. C. E. Grunsky, C. E., formerly assistant State engineer in California. Mr. Grunsky's paper, the result of several years' continuous study of the conditions affecting irrigation in the San Joaquin Valley, will prove of general interest to all irrigationists, and the ample and clear illustrations which accompany it of the methods and works employed render it of the greatest practical value to all interested. In addition to these papers, a translation of several chapters from a work on "agricultural hydraulics" by the French expert, Charpentier de Cossigny, has been prepared for and accompanies the special agent's report. A very condensed review prepared by him of irrigation conditions in foreign countries is also added.

The principal map attached to this report, constructed from data carefully gathered by the special agent in charge and the office of irrigation inquiry under him, is designed to present as an object lesson an illustrative statement of the progress in areas and acres of the work of reclamation by irrigation in the arid and semi-arid region west of the ninety-seventh meridian of longitude west from Greenwich. It serves to show not only the progress of irrigation itself, but the manner in which the American pioneer has been and still is in the habit of seeking and obtaining under his own inspiration and judgment, a home upon the public domain, and by his own efforts in combination with those of his neighbors, organizing industrial security for his home, himself, and his family. There is another lesson to be learned from this map, and that is, that the progress of such settlement and reclamation as it exhibits is also steadily increasing our knowledge of the water supply, while it is steadily tending to encourage the investment of capital in the work of agricultural reclamation and cultivation by means of irrigation. In this wise the use of water is proven to be the conservation thereof. It will be observed that the areas of cultivation along the principal water courses and within the drainage basins are growing in extent quite rapidly. This is a proof of the improvement in character of the works constructed, and in the methods of supply, means of administration, and the distribution of water. With these larger areas will be found a numerous body of very small ones, almost beyond recognition upon the scale allowed for the map, but from which the observer and student can see that the hardy pioneer is pushing across every mountain basin, through foothill sections, and up all the small valleys, seeking surface and underground supplies from which he may obtain water sufficient to make fertile the wild and waste lands which need only the touch thereof to make "the desert bloom and blossom as the rose."

WORK ON THE GREAT PLAINS AND THE RESULTS.

The final reports of the artesian and underflow investigation were completed as the law required. The thorough and comprehensive character of these reports, with the series of maps and profiles and illustrations that accompany them, is apparent on the most casual examination. The work of correlating effects and results which necessarily fell upon the special agent in charge, whose duty it has been to note the same over the whole field of inquiry, warrants him in stating that the direct as well as the indirect results, the latter of which are to be felt hereafter even more positively than at present, show that no expenditure on the part of the General Government has achieved such large and immediate benefits for so small a cost.

During the season of 1891, additional interest was aroused by the irrigation of two farms in South Dakota with artesian water, under the direction of the chief engineer of the investigation. By this means systematic instruction was given, which so greatly encouraged the farmers and the people generally, that capital remained that was preparing to withdraw, and new investments have been made on every hand. In a certain degree, the same state of things appear in all the other States, covered by the artesian and underflow investigation. In Nebraska, where, in 1890 there was not a single irrigation enterprise in practical operation, there are now several scores of separate works under way in the western counties, by means of which a large area will be brought under cultivation, heretofore given over entirely to stock. In western Kansas the beneficial influences, direct and indirect, have been as strongly felt as in the Dakotas. When the work began, in 1890, the counties west of the one hundreth meridian of longitude were in danger of being entirely abandoned for agricultural purposes. As, however, the existence of the underflow waters in the valleys of the Arkansas and Republican rivers in Kansas, of the South Platte in northeastern Colorado, and the North Platte in southwest Nebraska, were being established by the assiduous labors of the investigation, the fears caused by the recurrent drought have ceased. The existense of underflow or phreatic waters at varying depths and quantities throughout the length and breadth of the great plains region has been in a large degree tentatively established by its work, and that fact has given great encouragement to the pioneer farmers and communities in western Kansas. Encouragement has also been given, by the large work done during the past twenty-one months, to agricultural enterprise and industry in southwest Colorado, in eastern New Mexico, and throughout Texas west of the ninety-seventh meridian. The practical work of construction and cultivation which is in progress has resulted in great part from the impetus given to energy and enterprise by the same influence under the small appropriations made by the Fifty-first Congress.

In an address made to the students of the North Dakota Agricultural College, and to other bodies in South Dakota, in the month of March, 1891, by direction of the Secretary of Agriculture, the special agent endeavored to sum up the economic possibilities of the investigation under consideration. He said:

> For my purpose I assume, temporarily at least, that the reclamation of the great plains is not to be accomplished by any great system of water storage. I assume, also, that, taking the plains as a whole, great systems of canals and other large surface works will not be a necessity. I am, of course, cognizant of the fact that there are large areas in which surface storage and distribution on an extensive scale may be required—indeed become a necessity, but the reclamation of the division I have outlined, the 700,000 square miles defined as the great plains, is to be accomplished by a multitude of small detailed works, and must in the end be largely the result of neighborhood and individual exertion. Along the broad valleys of some of the rivers that infrequently cross those plains, there will necessarily be both surface and sub-canals or ditches on a large scale. But the security of the agriculturist is to be chiefly accomplished by small farm storage, by the impounding of the little streams, by the utilization of springs, and by the restoration to the surface through artesian drills or by the mechanical lifting from other bored wells, of the waters that are stored below the surface soil in the earth itself. The strata below that soil are for great distances a series of huge sponges, wherein the lost, imbibed, and percolated rainfall will be found to be stored.
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> There is not then a farm of 160 acres in extent as now located upon the great plains region upon which the farmer need fail in the worst year of drought to obtain a living for himself, family, and stock, keeping free from debt also, provided he will utilize the small natural supplies of water beneath his feet, and content himself at first with direct cultivation of only so much of the land in his possession as may be nec-

essary to make certain the supply indicated. The rainfall everywhere appears to be so conserved by the nature of the known stratum beneath the soil that any man with a quarter section can secure and distribute the requisite moisture, that may be absolutely needed for from 10 to 30 acres of tillable ground. I am talking of the day of small things and beginnings, and urging the consideration of security therefor. Thirty well tilled and watered acres will feed and care for family and stock, and will also enable the plains farmer to enlarge and take better care of his stock, thereby increasing income and aiding him to obtain in the near future and as necessary a greater share of a more permanent water supply.

WATER CONSERVATION AND MANAGEMENT—THEIR SCOPE.

The more thorough the investigations conducted by this office have been the wider and more comprehensive the field became. It is perceived that the natural phenomena and conditions relating to the cultivation of the soil by irrigation extend far beyond the mere limits of reclamation or agricultural economics in the region affected by a deficiency of rainfall and humidity. The problems underlying the subject relate themselves to the greatest of physical and cosmical facts. They make a draft on the one hand upon the sciences from topography to chemistry, and on the other hand, they embrace somewhat of all the great economic factors which go toward the solution of largest sociological problems. Systematic irrigation involves not only successful reclamation, but it embraces intensive cultivation, small farms and orchards, largely increased and specialized production, intelligent direction under the educated brain and trained hand, with the massing of cultivators into highly organized communities. Important as are the influences involved in these conditions, they by no means include the most significant of the problems that arise. More and more the conduct of the investigation and inquiry that has been committed to this office tends to prove that a right understanding of the magnitude and character of all that is included in water conservation and management must be a necessary condition of successful agriculture. One statement made by Geologist McGee at the Washington meeting of the American Association for the Advancement of Science, will serve to illustrate this. That gentleman described a professional trip through Mississippi. Over one-fifth of the area of that State, if recollection serves aright, was stated to have been rendered unfit at present for cultivation; first by the reckless destruction of the timber, and next by the torrential effects upon the soil of the heavy rainfalls. The denuded land had been torn into gullies and ravines, and thereby became worthless for industrial use. The decrease in the level of the Great Lakes, which is generally accepted as a result of deforestration, is another evidence of the want of proper knowledge in dealing with the earth and its laws. The destructive floods of the Mississippi and Ohio rivers are also in proof. The effect of excessive humidity of undrained lands, and the existence of marshes and similar areas, all belong to the largest problems involved.

The utilitarian and hygienic factors connected with town and city water supplies are a part of the work that some day will be correlated and directed with the observation of other and related phenomena and conditions, under the direction of the Department of Agriculture. A knowledge of the laws of climatology will establish conclusively that irrigation combined with drainage—that is, of water management in the large sense—is an absolutely necessary condition of successful agriculture. It is seen by even a cursory examination of the facts that the conservation and distribution of water may be made as serviceable in obtaining security for crops where the rainfall is excessive as it must necessarily be in making possible the reclamation of arid lands. The question of heat and consequent evaporation far more than rainfall during a given season will decide whether or no a growing crop will be fully matured. Many questions besides the more simple ones involved in the act of applying water to the soil are bound up in the problems of surface conservation and management, as well also in the conditions of earth or phreatic waters. It is remarkable how very little is known as to the extent or character of controlling phenomena in the matter of subterranean water supplies. Even the examinations made by the artesian and underflow investigation, simply objective as they have necessarily been, go a long ways towards disturbing pre-accepted theories of artesian and drainage supply. The rise and fall of the sub-water plane in cultivated valleys or other areas is one of the conditions which at no distant date the physicists engaged in correlating for economic uses such phenomena as are here suggested must take into serious consideration. Two years since, for example, it has been stated, that in Hocking Valley, Ohio, a region which is certainly not deficient in rainfall, the entire water plane, as shown by the wells sunk from 20 to 40 feet below its usual level. The continued changes going on beneath the crust of the earth projects a speculative inquiry, which may, however, have something of importance in it, as to how far the disintegration of rocks and strata may affect the phreatic supply. Water forms a large proportion of all rocks or strata. Again, no one has any systematic knowledge of the extent, egress, or ingress of subterranean channels and the volumes of water they convey to or from the ocean. The British Government printed, among other papers relating to the famous explorations of the ship *Challenger*, one by the chemist of the expedition, which, with maps, is designed to illustrate the density of the ocean waters at various depths and conditions. In this paper attention is called to the fact that a greater proportion of solid matter is found held in solution in such portions of the ocean as are regional with the arid sections of Asia or Africa. In other words, it is indicated that the fertilizing qualities of the soil have long been systematically washed through silt-bearing streams in enormous quantities into the ocean itself. Surely, then, the whole subject of agronomic hydraulics presents features of the greatest importance.

But the work of this office was defined and, in an indicative sense, limited by the terms of the law, in virtue of which it was organized by the Secretary of Agriculture. Its work has been directed by very simple yet comprehensive terms, and demands an inquiry "into the cultivation of the soil by means of irrigation." To that end this report now directs itself.

STATE SUPERVISION OF IRRIGATION AND WORKS.

One of the serious problems pressing steadily for consideration is that involved in the question of supervision over works and water supplies by the States interested in the reclamation of arid lands. At the present date there is not a properly equipped State engineer's office or board of water control in existence. Only two States have engineer officers with any powers approaching the needs of hydraulic administration. One other has provided for the supervision of artesian waters. The work of such oversight and control must be done by the States themselves; first, through a competent engineer's office or board of control, of which the engineer shall be a member; and second, by the establishment of municipal subdivisions, administering through popular control by practical experts the water supplies at the command of the district. Irrigation construction and administration is not a matter for haphazard movements or mere speculative endeavor. It involves, practically, the organization for Americans of a new system of agriculture. In the progress of that system it is certain that great profits are to be achieved. It is equally as certain that the irrigation cultivator must be a person of intelligence, of keen capacity, a faithful student, and untiring worker; otherwise he will be left in the race. It is already indicated in such a degree as to point to an almost positive result that the effect of systematic reclamation within our Western States will be a great subdivision of land holdings. As a necessary consequence of such subdivision the isolation of farm life will vanish, and agricultural or horticultural town or village centers will become a marked feature of settlement. The character of works to be employed, the facts of climatology, the relations of the atmosphere to the water and the soil, the adaptability of the plants to different zones, and at least a primary knowledge of hydraulic engineering will become a part of the training of every successful cultivator of the soil by means of irrigation. The administration of the water supply involves subtle questions of law and economics, and goes for illustration back to the very dawn of history.

All communities, the cultivation of whose food products has been achieved by the artificial application of water to the soil, have in a more or less elementary manner been compelled to organize some form of governing the water-using people, directing and controlling the constructions needed for the storage and conservation and distribution required for the purpose of tilling the land. The Pueblo Indian and the Mexican farmer alike appoint or elect their local water masters and submit themselves with great faithfulness to customs and provisions more or less stringent in character. An examination of the habits and customs of all communities long using irrigation brings to view the same condition and establishes the same order of procedure. It is evident from even a cursory study of the great hydraulic systems of ancient days in Mexico, in South America, in Northern Africa, or Arabia, or throughout the great oriental countries, that the most elaborate codes of laws were established by the central authorities, whatever character they may have been, and that these were supplemented by local regulations, a great many of which have survived to the present times in the rehabilitation or recreation of these great works. In Egypt, Ceylon, and British India the same necessity of rigid supervision and careful administration has been imperatively settled. In the British Australian colonies of New South Wales, Victoria, and South Australia, the discussions show a full appreciation of oversight and control.

In New South Wales, Queensland, Victoria, and South Australia departments of water supply have been organized. The two first-named colonies have in their employ a body of able engineers and other professional men, whose duties are directly associated with the conduct of the water trusts authorized for irrigation and for domestic purposes. They are also charged with the study of climate, geology, topography, and forestry in connection with the requirements of a proper conservation of the property held by the state in the natural waters. Queensland has recently undertaken through its water department a systematic series of borings for an artesian supply. Victoria and South Australia have made extensive contracts with well-known American organizers for the reclamation of 250,000 acres in each of the colonies named. The maps and reports that have been prepared and published by these colonial governments are among the finest and most thorough of their character issued in the world. In Victoria especially no extensive system of irrigation can be inaugurated except upon plans approved by the government engineer, while the construction of the works required is carefully watched by the water supply of the department. Of course it is true in these as in other parts of the British dominions, where the storage of water is a necessity for successful agriculture, that questions of statecraft in the way of colonization, maintenance of peace over subjugated races, as in India, and methods of insuring loyalty to the mother country are all involved in the plans which have been adopted alike in South Africa, Ceylon, India, and the Australian countries.

The general existence of all these tendencies is pointed out not by way of argument for any plan or scheme or policy, but in order to illustrate what seems to be the natural and necessary law controlling irrigation work and the communities connected therewith. In the States west of the ninety-seventh meridian upon this continent, so far as any action has been taken it is to provide for the right of appropriating the water, to give a means of legal appeal in case of contest, and to leave all the rest to the friction of an aggressive and struggling existence. California has relegated, and very efficiently, local construction and distributive supervision to the communities interested. Several other States have in part followed this lead. But the laws establishing such a system touch in nowise upon the greater needs, soon to be pressing ones, involved in the demand for water storage for the protection of river and stream sources, for the insurance of security to life and property, by compelling proper construction in the great storage works that must be built ere long, for the enforcement of systematic drainage in the interests of health as well as agricultural economy, and for the proper dealing with a thousand other important questions that might be marshaled here and that can not safely be left to the accidents and emergencies that arise from a day-by-day avoidance of public obligations. The Utah settlers, who first organized neighborhood systems of irrigation upon an extensive scale within our boundaries, have, by the peculiar nature of the obligations that control them, succeeded, without definite codes of law or even an efficient water police, in coöperatively maintaining equity among the users. Nowhere else, except in the survivals referred to among the Pueblo Indians and Mexicans, or in the new organization expressed in the California districts, have we begun to reasonably realize the needs involved in this matter of State control of local supervision. The constitution and laws of Colorado have been directed almost wholly to securing the rights of appropriators, the freedom of conveyance, and a reasonable method of settling disputes while proclaiming the public character of water property. The State of Wyoming, modeling its legal action upon that of Colorado, has also simplified and improved upon it. So far as the protection of appropriation, the guarding against this undue and unjust exercise, and the control of ditches in that direction, its State board of control and the engineer's office are better equipped than elsewhere is the case. Consideration of the questions involved in these suggestions must ere long be seriously taken up.

THE GROWTH OF RECLAMATION FOR 1891.

The year 1891 has been marked with great activity in the direction of reclamation enterprises on a large scale, and in the development by means of irrigation of numerous small localities west of the one hundredth meridian. This beginning of cultivation, generally upon small areas of land, is even a more notable illustration of economic progress than the organization of great enterprises whose works are designed to ultimately reclaim and bring under use several millions of acres of land not now adapted to agriculture. If the lines of cultivation and migration during the year 1891 were laid down upon a map, they would show within the arid region of the United States movements so defined as to make a distinct parallelogram. In the region between the ninety-seventh meridian and the foothills of the Rockies, almost from north to south, there has been a decided growth of settlement and a marked increase of cultivation. The more distinctly this growth has been brought under the influence of irrigation development, however supplied, the more certainly it shows evidences of permanent prosperity.

The increased feeling of security in the Dakotas has been followed by as marked an increase in acreage and production. The Black Hills portion of South Dakota, for example, has almost escaped attention during the pendency of the present inquiry and discussion. In 1889 it was estimated that some 13,000 acres were cultivated chiefly for forage and cereals, by means of irrigation supplied by small ditches. In 1890 the area so cultivated was estimated at 20,000 acres. In his final report as geologist for the Dakotas in the artesian and underflow investigation, Prof. Garry E. Culver places the area of irrigated lands in the Black Hills section at 50,000 acres. In Nebraska and Wyoming, moving southward on the eastward line of the parallelogram, there will be found to be a considerable increase of population and a much larger proportionate increase of effort in the direction of extending reclamation works over the arid lands. The estimated area of increase for the year in Wyoming is 856,700 acres. That of Nebraska, for works partially finished or in progress, shows an estimated increase of 135,000 acres under ditch and of 30,000 acres under cultivation.

The public feeling is turning strongly in the direction of a smaller number of acres and a more careful cultivation, with an eager desire to secure, whenever possible, an independent water supply by which to make farming operations secure. Another marked feature of business enterprise and public opinion is to be found in the fact, as indicated by discussion in the press and the correspondence of this office, that the officers and managers of mortgage companies and of farm-loaning banks all express themselves as most eager to aid the development of water supplies under such circumstances as will assure upon the Great Plains the disposal for cultivation of the lands they hold, or control as security, in areas much less in extent than has heretofore been held in that region.

Both north and southeastern Colorado have been benefited by the movement under review. Many small enterprises are also recorded in the eastern portion of that State. A special development of eastern Colorado is the growing interest and effort in and for the establishment of reservoirs, both large and small. The valley of the Arkansas is marked by the progress of a number of great enterprises, one of which is distinguished by its efforts to utilize open basins and depressions south of the river for storage purposes. One engineer reports seeing in the eastern portion of the State from an elevated point 134 storage basins, small lakes, or ponds all lying within the range of his vision. One of the chief objects of this effort is to obtain a supply for and store the same during the winter months, so as to be able to keep the ditches running when planting begins in the spring. The discussion of the past three years over the advantages and needs or otherwise of storage reservoirs has certainly developed some features of hydraulic engineering which, when the discussion began, would have been considered audacious in character. In spite of the arguments relative to loss by evaporation and the wates claimed to follow all attempts to bring mountain supplies long distances without high altitude storage, the tendency is quite marked towards a development of storage basins upon the open plains. Something of this is due to the increase of knowledge which has followed the artesian and underflow investigation as to the extent and condition of precipitation over such large areas of land free from mountain range and gradually passing into the prairie formation. It has become apparent, under the close local observation which has been aroused, that if the local precipitation can be thoroughly conserved it will with the current daily rainfall go far towards supplying the needs of the farmers of table-lands and plains. Experimentation in such directions is a necessary feature of its development and progress. As a result of all this there is already a considerable increase in cultivation and a promise of a much more rapid growth in the immediate future.

The increase in security in western Kansas within the past year and a half is a notable tribute to the discussion, interest, and investigation that has followed the work ordered by Congress. The people of the new Territory of Oklahoma have already found it necessary to consider the need of preparing for a moderate degree of water conservation and distribution. The fertile agricultural area, on which they have so rapidly built a new commonwealth, is liable to the same drought and depression that has elsewhere along the eastern line marred agricultural settlement with variable rainfall and hot winds that desiccate. The able and almost minute report of the geologist for Texas in the artesian and underflow investigation, Prof. Robert T. Hill, as well as evidence given elsewhere in this report, shows a marked increase in activity in cultivation and growth of population throughout the central, western, and northwestern portions of Texas. But the largest result of irrigation enterprise in the opening of a great area yet seen is that which is making so marked a development in eastern New Mexico. The valley of the Pecos and the plateau region of the Raton Mountains have, until within a year or two, been practically unknown to the average American as a part of the common country. What little use has been made of this extensive area during the past twenty years has been confined to a sporadic occupation thereof for the feeding of stock and the raising of sheep.

The irrigation development of the past two years is notable in character, not only because of the extent of the works and the capital invested or of the area opened, but because, in the case of the more northern enterprise—that which is located upon the Raton plateau—there are engineering and agricultural experiments under way, which, if they prove successful, will add vastly to the value and utilization of great table land regions that are now supposed to be adapted only to pastural purposes. The two systems in operation upon the Maxwell Grant, covering an area of 65,000 acres, and supplied from branches of the Canadian and Cimarron rivers—streams whose mountain sources are fed from the vast precipitation of the Sangre de Cristo Range—present in their development the possibility of a great, even vast, increase of the agricultural area of the arid region. The altitude at which successful farming is carried on, the still higher range at which healthy orchards bearing an ample return of fruit in fine condition were seen during the summer of 1891, the remarkable engineering experiments by which with works of a simple and not costly character the mountain supplies are brought out and stored upon the open table land and from such storage distributed to the farm lands under them, all these point to both the possibility and probability of utilizing a very considerable proportion of such higher table lands and plateau region. The experience now being gained will probably encourage experiments and operations in favorable northern latitudes. The Special Agent after his visit to Northern New Mexico and elsewhere, expressed the opinion that the success of the open table land reservoir system illustrated on the Maxwell Grant, in Southeast Colorado, at Nampa under the Boise River in Idaho, and more recently in the conservation of water in the open lagunes which are being appropriated under the Bear Valley system in Southern California, will add from thirty to fifty million more acres to the arable area of the country. Certainly, that portion of the table land or plateau region which will be affected by the success of the Maxwell system will be likely to come under the influence of a development that, bytaking advantage of every opportunity of storage, large or small, and of all available phreatic supplies that may be found, will tend to the establishment in time to come of a mixed arable and pastoral farm settlement. Such a statement may seem quite speculative in character, but to the observer making the same it is based on both comprehensive and minute inquiry, facts, and conclusions, and it enforces on him a remarkable and even early possibility of successful achievement, or at least the decided beginnings of the same.

The north and south lines of the parallelogram of movement and development already indicated, runs on the north, chiefly through Wyoming and the southern portion of Idaho, and further north up the Valley of the Yellowstone and over the Rocky Mountains at Missoula, into the Pacific northwest, east of the Cascade Range. The increase of population has not been large, but steady in character, while the increase in reclamation enterprises is on a decidedly large scale, and the investments made and enterprise shown in construction, point decidedly to an early effort to encourage and direct active settlement. Several great areas are opened up under this northern line. Perhaps the most direct increase of cultivation and the systematizing of necessary works upon the north is to be seen in the Gallitin Valley, Montana, where irrigation has practically been a success for the last twenty-five years. New and extensive areas that will soon invite occupation are to be found in southern Idaho, eastern Washington, and Oregon, as well also in northern and central Montana, east and west of the Rockies. Extensive reclamation works are in progress in that State, but considerable attention must yet be given to organizing administration of the water and occupation of the land.

On the southern line the movement of population is slower. It is naturally somewhat different in character to that which moves upon the northern line, because the climatic conditions of New Mexico and Arizona invite a somewhat different type of population; but the horticultural development and the large promises of return it carries, are building up a very distinct and definite character, cultivation, and settlement therein. The western line of the parallelogram suggested is following northward from the Colorado desert through the great valley regions of California, until it meets and mingles with the movement that along the northern line has already begun to occupy the southern portion of eastern Oregon. The great interior of the region thus defined has felt to a considerable extent, though not generally over its whole area, the same interests and activity, which, under investigation, is shown to be most directly along the lines given.

The progress of irrigation reclamation is concretely indicated in a statistical form by a table that follows. There is but little satisfaction in presenting estimates, but the limited force, with the equally as limited time at command, forbids doing anything else. This claim can be made for the figures annexed, and that is, that they are all reasonable and it is believed well within the facts.

Irrigation areas and artesian wells west of the ninety-seventh meridian.

State and Territory.	Acreage.					Number artesian wells.*
	Under ditch.			Cultivation.		
	1889.	1890.	1891.*	1890.	1891.*	
Arizona	529, 200	643, 450	660, 000	310, 100	315, 000	a45
California	3, 294, 000	4, 044, 000	4, 500, 000	3, 444, 000	3, 550, 000	3, 500
Colorado	2, 813, 273	4, 082, 738	4, 200, 900	1, 585, 000	1, 757, 162	4, 500
Idaho	715, 500	1, 181, 500	1, 200, 000	327, 000	330, 000	12
Kansas, west of 97° of longitude	500, 000	890, 010	900, 000	100, 000	120, 000	250
Montana	986, 000	1, 100, 000	1, 250, 000	400, 000	410, 000	86
Nebraska, west of 97° of longitude	50, 000	65, 000	200, 000	10, 000	40, 000	100
Nevada	142, 000	150, 000	150, 000	75, 000	100, 000	76
New Mexico	638, 455	677, 315	700, 000	460, 000	465, 000	10
North Dakota	....	1, 000	2, 500	1, 500	2, 000	b670
Oregon, east of Cascades	75, 000	100, 000	125, 000	45, 000	45, 000	6
South Dakota	100, 000	100, 000	100, 000	22, 000	54, 000	b950
Texas, west of 97° of longitude	200, 000	340, 000	350, 000	160, 000	160, 000	c1, 000
Utah	700, 000	700, 000	735, 226	413, 000	423, 364	d2, 524
Washington, east of Cascades	75, 000	150, 000	175, 000	60, 000	75, 000	10
Wyoming	1, 946, 876	e2, 172, 781	e3, 038, 481	e175, 000	e180, 000	6
Total	12, 765, 304	16, 367, 794	18, 286, 207	7, 577, 000	8, 026, 526	13, 696

NOTE.—The figures of this table are necessarily estimates, made by the Irrigation Inquiry, but they are all well within the facts. All the wells given come within the definition of "positive" artesian water adopted by this office.

a The first successful artesian well in Arizona was drilled in 1881; the total given was reached by 1888.

b The deep artesian wells in Dakota, now completed, number 105; the shallow flowing or drift wells are estimated at less than 800. The State engineer reports over 100 township wells contracted for and in process of construction, and about 250 more private enterprises are reported. In North Dakota there are 19 deep flowing wells, and about 650 flowing shallow wells in drift deposits in the Red River Basin.

c In Texas, in 1890, about 700 flowing wells, deep and shallow, were reported upon, and at least 300 more have since been bored.

d The Utah total is the statement of the U. S. Census accepted as correct in the Territory, up to July 1, 1890. The number has since been increased sufficiently to warrant the estimate of 2,800. These are all shallow depth, flowing wells, supplied from drift deposits. This is an addition of 276 wells, making the total 13,971.—Statement of Territorial experts.

e From report of State Engineer Mead, 1889-'90, and of Mr. P. L. Naismith, assistant engineer, for 1891, made to this office. The figures given for 1891, as "under ditch," are from the State records; those for 1892 include 856,700 acres as covered by works in process of construction or projection under prior appropriations.

The irrigation developement in Wyoming is as remarkable as that of any portion of the western region. Up to January 1, 1891, the following are the figures:

Total number of ditches	3, 050
Total length in miles	5, 464
Total capacity in second feet	2, 563, 900, 000
Total acreage under ditch	2, 172, 781
Total estimated cost at $3. 62 per acre	$7, 865, 467. 22

For the year 1891, closing December 31—

There were of applications for ditch appropriation	210
Covering a mileage of	970
Designed to serve (acres)	856, 700
At a cost (estimated) of	$3, 464, 269

It is true that the projected operations of 1891 are as yet mainly in the air, though a considerable proportion of the work needed is under way, and the greater portion will finally be constructed.

Another most notable development is in the matter of storage. Colorado is especially active in that direction. The State engineer's report for the two years from 1888 to 1890, shows the following totals:

Reservoirs recorded in his office up to 1890	354
Ditches on file there 1888; number of	2,679
Estimated and stated mileage of same	10,023.45
Number of ditch appropriation recorded from 1888 to close of 1890	1,380
At an estimate of 4 miles to each ditch, the total will be	5,420

The report for 1886-'88 shows a total of 74 storage reservoirs, most of them smaller than the latter constructions, while a number of them were only intended for stock purposes. The increase in two years has been 280, and if we to allow a filing of one-half more, or 140, for the year 1891, it would increase this class of constructions, more of which are under way, to 494 storage sites. A great many of these, the majority in all probability, belong to the class of plains or open valley storage which has been referred to. The increase in ditches and mileage for the past year will certainly be one-half the total given for two years covered by the State engineer's report, 690 ditch filings, with an estimated length of 2,710 miles. Adding these totals together we shall have for Colorado, at the close of 1891, an estimate

Of reservoir sites and construction	494
Of ditches constructed and under way	3,369
Of mileage, recorded and estimated	18,153
At 300 acres per mile, this will give a total as under "ditch" of	4,445,900

Another step in the conservation of water within this region has been in the passage of the act passed by the last Congress authorizing the President to set aside by proclamation any portion of the public domains as forest reservations as may be desired. It is to be hoped this measure will be so administered as to include the sources of all inter-state waters. The need of such reservations will become at once apparent to anyone who will examine a proper map with critical eyes. It will be seen that the controlling power over a continental water supply is held both geographically and hydrographically by the minority in physical area, civic organization, and population. Three States, embraced within the area of the Rocky Mountains, holds the sources of at least 60 per cent of the western waters of the Mississippi system, and at least 90 per cent of all the flowing streams west of the one hundredth meridian. It is a subject of profound interest and one that must command the attention of legislators, state and national.

The deep artesian wells of South Dakota now completed number 105. The shallow flowing wells of the drift area, chiefly found in Miner and Sanborn counties, are not less than 800 in number. According to the State engineer of South Dakota, over 100 public artesian wells have been authorized and contracted for. As many more have filed applications in his office. Some two hundred and fifty private artesian enterprises are reported. There are in North Dakota 19 deep wells reported and about 650 shallow flowing wells, nearly all located in the drift deposits of the Red River basin, in the northeast section of the State. About 150 wells have been added to the number previously reported by the artesian and underflow report of 1890 as located in western Kansas and Nebraska. In the San Luis Valley, Colorado, some two hundred shallow wells have been bored during the past year.

In New Mexico there are now ten or more flowing artesian wells near Springer and at Roswell and Eddy, in the Pecos Valley. Several experiments elsewhere in the Territory are under way. The successful boring of artesian wells in Arizona is of considerable importance and bids fair for future development in this important direction. There is no doubt whatever that Arizona has a large supply of phreatic waters, with at least a negative artesian character—pressure sufficient to rise in the bore, if not to overflow at the surface. In western Texas (west of ninety-seventh degree) there were reported in 1890 about 700 flowing wells. At least 300 have been added to the tally, while the number of bored wells with an ordinary phreatic supply and pressure has more than doubled in the past two years. Up to July 1, 1890, the total (2,524) given in the table for Utah, being the same as reported by the United States Census Office, is accepted as correct. Since that date, however, the increase justifies a present estimate of 2,800 flowing wells in that Territory. The chief fact about recent development is the achieved certainty of a large phreatic supply, which is certain to be reached and utilized to great benefit by means of bored and driven wells. In the Pacific Northwest there has been some notable well development, and in California an increased irrigation supply is being obtained from that source. Other development in the direction of drainage supplies is found in the increased number of underflow enterprises, such as bed-rock dams, drift tunnels, gravel-bed gravity or pumping, the opening of springs, the lifting of water, and the increase by sub-canals of underflow supply. Altogether, the activity and development in reclamation works has been very notable.

THE ART OF IRRIGATION AND AMERICAN SUCCESS.

The art of irrigation, probably originating in Southern Asia, has been known from remotest historic times. The Chinese, the primitive inhabitants of India and Persia, those contemporary with the kingdoms of Babylon and Nineveh, and who then inhabited the country lying between the Euphrates and Tigris, and finally the Egyptians, all appear to have made extensive use of irrigation. The Romans borrowed the system from the East, and transported it into Italy and the south of France. Lastly, the Arabs, also coming from the West, introduced it into Spain. Since then, however, the art of irrigation has remained almost in the same condition as at that time, and in spite of the unprecedented spread of modern civilization and in spite of the indisputable progress made of late in agriculture, but a small amount of territory, comparatively, has been reclaimed by irrigation. The largest progress of area in later years has been made in British India, where about 30,000,000 acres have been either newly reclaimed or made secure to the cultivator by the construction of new supply works. The larger proportion of this great work has been done within the last thirty years, and one-half of it at least within the past fifteen years. The amount invested exceeds $150,000,000, and the profit thereon is large though obtained from indirect methods, such as land revenue and the increase for industry found in the security and peace of the empire. A considerable proportion of the works have, however, yielded a fair per cent of profit for several years on the large capital invested. In the northwest provinces, for example, where the administration has been able to concern itself with some simple questions, though of great magnitude, such as the reclamation of new lands, the restoration on purely engineering grounds of old works, the renewal and settlement of land workers or ryots, and the framing and execution of simple laws and regulations based on old customs and rules, the direct profit resulting on capital invested has been sufficient to satisfy the most exacting of investors.

The progress of the United States is next in order. In the past seven years the actual area of reclamation by irrigation cultivation has increased from about 5,000,000 acres to at least 8,500,000 acres, or, according to the table accompanying this report, 8,026,526 acres. There are small areas scattered throughout the region beyond the one hundredth meridian west from Greenwich, of which no reports have been made, sufficient in total amount to increase the figures to over 8,500,000 acres. But greater activity than this addition of 3,500,000 acres to the area of cultivation is seen in the growth of important hydraulic works. "Under ditch" this office reports for 1891 an estimated area of 18,286,207 acres. The largest proportion of this great addition to the cultivatable area will be made available for use within the next year; and by the opening of the World's Columbian Exposition, the United States may anticipate the cultivation by means of irrigation of at least 17,000,000 acres of land that within the past decade have been declared by learned authority as wholly irreclaimable, worthless for agriculture, useless for tree planting, and hardly fit for even the grazing of scraggy sheep and the broad-horned steer. Under projected works or partially constructed, nearly 5,000,000 acres may be added, making in all as now reclaimed or in process of reclamation not less than 25,000,000 acres.

THE WORK OF AMERICAN ENGINEERS.

The map prepared from data furnished by the special agent in charge of the irrigation inquiry clearly illustrates the mode of settlement and occupation, and indicates also what must be the principles controlling the work of consulting engineers. Some sharp criticisms of the hydraulic and construction conceptions and execution of American engineers engaged in irrigation work are finding their way into the great and general discussion now in progress. A large amount of this criticism is pertinent and well directed; but very much proceeds from engineers trained in other lands, or from their younger admirers, who endeavor to imitate or mold after formulas and systems adapted to other conditions. There is doubtless considerable truth in Mr. Cope Whitehouse's criticism that "we have lots to learn in western America before we can talk irrigation." That may be unquestionably true, but there is good reason for denying the correctness of the further remark, attributed to the same eminent engineer, that "with scant exceptions" we are "below the level even of the minor modern constructions to be found among those Oriental nations whom the American engineer has been taught to despise." Putting aside the self-contradictory segment of this dicta it must be said that a large proportion of the important irrigation works constructed in our Western States during the past six or eight years are the equals of even the Anglo-Indian works, after taking out such great enterprises as the Upper and Lower Ganges canals, those of the Jumma, and a few others. There are American works that will stand comparison with any in the world not constructed of masonry. Among such must be considered the very notable system known as the Bear Lake and River irrigation works in southeast Idaho and northern Utah; the Idaho and the Nampa canals in the Boisé Valley, Idaho; the splendid constructions that are progressing in the Modesto and Turlock, and the Colusa irrigation district of California; the very clever work done on the Maxwell grant in eastern New Mexico, where in both cases there is a large degree of engineering adaptability shown in devising plans suitable for climatic and topographic conditions. The great activity now displayed in Colorado with regard to the storage of water is giving play to skillful use of engineering and expert knowledge and capacity. There is not to be found elsewhere the equals in capacity and economy of service, in results obtained, in methods of conservation, and in modes of distribution, especially in the latter direction of some of the systems now in vogue in southern California. There is no more bold engineering than that which has already stood the test of time and the strain of most unusual stormy precipitation, in the Sweetwater and the Bear Valley reservoirs and dams. They clearly point the way to the large systems of water storage that are, as rapidly as needed, coming into use. And the new works, such as the Tuolumne, the Hemet, and others, that are under way show a careful taking advantage of past experience. The methods of distribution, the materials employed, and the skill displayed in the work accomplished by the service at Riverside, Ontario, Redlands, and the Alessandro and Perris districts, are almost if not wholly unequalled in the history of irrigation engineering, ancient and modern, and their projectors, engineers, constructors, and administrators, are all Americans. Only one important California work has been devised by an engineer trained in the great Anglo-Indian school of irrigation works, and it has received very sharp criticism. The able engineers who have officially examined our systems on behalf of the Australian colonies of New South Wales and Victoria, as well as the more recently, the representative of the Russian Government, whose duties relate to the plans for irrigating the Asiatic oases now in possession of Russia, do not appear to share in the critical objections under consideration. The transfer to Victoria and South Australia of the energies and organizing abilities of the irrigation experts who made the settlement of Ontario, southern California, an era in fruit culture and economical water service, is a tribute to American capacity in that direction, which engineer critics can not afford to ignore. This reference is made not because the unfavorable allusions are undesirable as a spur to better efforts, but because their expression represents a point of view unfriendly to the progress of irrigation on lines already well defined. When it is really based upon a genuine desire to see security in construction combined with comprehensiveness in plans, it is too closely identified with the type of intellect and training which can only work to its best advantage upon the method of the paleontologist, who from one fossil bone can reconstruct the full skeleton of an unknown mammal.

IRRIGATION LEGISLATION.

During the year 1891 great activity and interest has been manifested in legislation, as well as in judicial decisions relating to water supply and its management within the States and Territories of the arid region. A brief review of the salient facts in connection with these is given.

In California the district irrigation system has been pressed steadily to a slowly growing success in spite of the fact that certain interests in various districts have made a strong legal fight against the laws and their operation. So powerful, however, is the feeling in that State in favor of this system that both the supreme and district courts uniformly advance all cases arising under them. The majority of such cases heretofore have been of a friendly character, intended to obtain decisions upon amicable presentations of disputed points of interpretation. During the year 1891 a number of cases have, however, arisen in deliberate hostility to the effective working of the laws and the constitutionality of their provisions. The reason of this feeling is not far to find. The effects of district irrigation in southern California and in the San Joaquin Valley have been so marked in both the peace produced and the profits thereof, that it has stimulated activity in the northern and more central portions of the great valleys of the San Joaquin and Sacramento. The organizations of districts projected, like the West Side and Sunset in Fresno County, the Madera, the Turlock, and Modesto, in Stanislaus County, and the three large districts in Colusa County have aroused feelings of hostility against the system on the part of many engaged in very extensive wheat culture or in the holding of lands for speculative purposes. To those acquainted with the conditions of wheat ranching in the portions of California mentioned it will not be a surprise that legal resistance should be made against well directed efforts under the district law of the small landowners and farmers to bring about better cultivation and the settlement of a larger population. They want more population and industry to bear the burdens of taxation and bring about improvements. Recently the State supreme court directed a retrial of a case in which the Madera district is involved. The constitutionality of the original Wright law was pressed by the parties against the district. This, it is reported, was more directly involved in the Madera case than in any that has appeared before the court, but the full bench threw out all such pleas and simply directed a re-trial upon an error made by the lower court in hearing some testimony not properly before it. It seems probable that with this conclusion there will be a cessation of attempts to legally obstructing the progress of the irrigation district system in California.

In Nevada the present district system has been applied and limited to the storage of water, leaving to irrigated communities themselves the task of managing and arranging with prior appropriators the community work or plan of distribution through the amicable purchase or condemnation of individual rights. One district has been fully organized under the law and embraces the Truckee Basin, with Lake Donner as a storage reservoir. Another one will probably soon be organized in the Humboldt Valley. In Oregon, at the last legislative session, elaborate provisions of law were made for the supervision and distribution of water for irrigation purposes. These provisions were of such a character as to lead almost inevitably to the enactment at the next session of a district system for the eastern part of the State.

In Washington, under an act passed at the last session of the State legislature, a district system has been organized. Several water supply areas have been formed into irrigation districts. Two of these are in the neighborhood of Ellensburg. A section of which North Yakima is the chief town has also been formed into a district. Others are reported, but no details have reached this office. The districts in Kittitass County it is claimed have proved a marked success, united the efforts of the people toward the improvement of their water supply, and aided in stopping neighborhood litigation.

The first legislature of the State of Idaho, in session from January to March, 1891, passed a memorial to Congress, which, as it represents very clearly the feeling in favor of a change in the national public land system and presents the argument therefor in a conservative manner, as a matter of information and as a part of the general record, is herewith embodied:

To the Senate and House of Representatives
of the United States in Congress assembled:

Your memorialists, the first legislature of the State of Idaho, would most respectfully represent:

That the State of Idaho lies wholly within the arid domain, and that agriculture is dependent upon irrigation. The reclamation and settlement of the agricultural lands must be accomplished therefore under different conditions from those confronting the pioneers in the humid portions of this country. The present land system is the outgrowth of the experience of humid districts, and is wholly unsuited to the conditions which prevail in this State, and as a result interposes serious obstacles to the rapid and prosperous utilization of our agricultural resources and the making of homes by those who are ready and willing to take part in reclaiming the desert.

Your memorialists would also respectfully represent that the most effective remedy for these evils, and the measure which promises the most beneficial results, not only to this State, but to the whole country, would be for Congress to donate to this State all the agricultural and grazing lands within its borders, under such restrictions as would safely and perpetually secure their utilization by actual settlers and cultivators of the land donated, and would respectfully offer the following as among the reasons for asking for such control and as justifying such donation:

That the reclamation of the agricultural lands imposes upon the settlers engaged in the work and upon the State government obligations and expenses not incurred in the humid portions of the country. Not only must ditches be constructed and the lands be prepared for the application of water before there is any return to the farmer, but with the multiplication of these works it becomes necessary for the State to exercise a supervision over them in order that those entitled to the use of the public waters may receive it. The expense of such supervision is of necessity heavy. In Idaho there are 2,000 ditches diverting the waters of over 500 streams. The examination of these claims, the determination of the priority and the subsequent division of the waters among the various claimants gives rise to problems which require both ability and experience on the part of those charged with their solution and requires the employment by the State of a large number of officers.

Thus far the Territory has borne the entire expense of the investigation of our agricultural resources and of the supervision of our public waters, and by the action of Congress granting the State the ownership of all the waters within its borders the expense and responsibility of such supervision must continue to be borne. The efficiency of this supervision is greatly impaired by the inability of the State to assist in any way in the reclamation and settlement of the desirable lands or to restrict the diversion of water on the less desirable. In this connection it must be remembered that the lands susceptible of irrigation is largely in excess of the water to serve them, and that agricultural values inhere in the water rather than in the land. Such selection should therefore be made as will secure the use of the water on the best lands, since they vary greatly in value and the quantity of water required. With no supervision the water may be so diverted that the quantity required for irrigation of one acre would suffice for the reclamation of two, three, or four acres of land in more favorable locations, but so long as this matter is left wholly to individual ability and inclination, so long will the public interest be lost sight of and wasteful and improper diversions be made.

Our experience during the past five years has shown the evils growing out of the control of the land being under one authority and the water under another. If the late Territory of Idaho could during the past ten years have controlled the disposal of the irrigable lands within its borders, it could, while disposing of it to actual settlers only, have afforded such protection to canal companies as would have given our agriculture four times its present importance and more than doubled our population. The most extensive and valuable bodies of irrigable lands in the State, those bordering our principal rivers, more particularly the Snake River, are untouched, because the experience in constructing canals and the time required for their completion places the work beyond the reach of individual enterprise and effort, and the general land laws have made colony or corporate enterprises too hazardous to be undertaken. The local government could do nothing to aid the work, both from lack of means and want of proper control. Another evil of the present condition of affairs is the tendency toward a separation of water rights and land titles. If the State controlled the lands it would be possible to connect water rights with land titles of all irrigable lands. That this is desirable is admitted by all familiar with the subject. It is both an aid in preventing monopolies in water by companies and securing its more economical use by farmers.

The importance of the pastoral interests in this State makes it desirable that pro-

> vision be made for the utilization of the grazing land in connection with the contiguous irrigable areas. These lands comprise a large part of territorial extent. They can never be made the self-supporting habitation of man, but furnish a valuable complement to the lands reclaimed—the first furnishing the summer's and the latter the winter's food supply. None of the present land laws make adequate provision for securing possession or management of these lands, and some further legislation is needed to meet the requirements of our prospective development and increased population. We believe, however, that it is impossible for Congress to pass a general law which will operate with equal justice and success on the arid belt as a whole. The conditions differ in different sections, as do our water laws. Idaho differs from Utah, and Arizona from Montana and Wyoming. The people of each section are the best calculated to determine the system best suited to their needs, and should be given the means of carrying it into effect.
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> The results already achieved are a sufficient guaranty of what can be accomplished under more favorable conditions. Under the territorial laws $10,000,000 was invested in irrigation works and over 1,000,000 acres of land reclaimed thereby. Not only has the value of the land been enhanced thereby from ten to one hundred fold, but its productive capacity has been correspondingly augmented. Such results are of interest and value to the whole nation, and we believe entitle the State to generous recognition. The provisions of the State constitution require the inauguration of the most systematic and complete supervision of the public waters yet undertaken by any Commonwealth in this country.
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> It is only, however, by uniting the control of both water and lands under one authority that our irrigation system can have the fullest measure of stability and success. We believe that the control of this subject can wisely and safely be intrusted to the State, since the practical knowledge of irrigation in this country is almost wholly confined to those engaged in the work. By endowing the State with means and placing upon it the responsibility for the development of our resources, a great impulse will be given to the diffusion of intelligence on the subject and to local pride in the character of our irrigation works. It will put the solution of this problem in the hands of the people best informed and most interested in its success.

An elaborate bill providing for the appropriation and distribution of water, the condemnation of land for canals, ditches, and conduits, empowering county commissioners and district courts to establish a maximum rate for the use of water, and providing also for the adjudication of right and priorities in appropriating, diverting, carrying, or storing water for beneficial purposes, was passed by the legislature. The governor, under date of March 21, returned the bill to the secretary of state with his veto. This document is one of decided interest, and so clearly gives the objections urged against certain forms of water management and administration that it will be read with interest. It is as follows:

> The general scope of this bill, as is shown by its title, is a very broad one. It aims to regulate one of the leading (if not the leading) industries of the State. A large percentage of our arable lands are properly termed arid, and without water artificially introduced will be valueless for centuries to come, as they have been for centuries past. The land exists in place. It can not be brought to the water—the water must be brought to the land. Only a small amount of our arid land is susceptible of irrigation by small and comparatively inexpensive canals, which are or may be constructed by associations of farmers, who divide the water among themselves and are quite independent of any statutory system of distribution and regulation. But by far the largest portion of the arid land must be irrigated by canals of great size and length, involving the expenditure of great sums of money and much time in their construction. These enterprises are the ones mainly affected by the provisions of this bill. It is true, the consumers of water are also intended to be protected in their constitutional and equitable rights, and though not numerous at present, it is fairly to be presumed will become very numerous, indeed, in the near future.
>
> But this can only happen when water is brought on or in the vicinity of the land to be irrigated. Up to the present no complaint has reached me that the rights and privileges of this class of our citizens have been infringed or threatened. It is one of the possibilities only of a more or less distant future that these rights may be infringed. In the meantime the possibility of rigorous and perhaps prohibitory restriction upon the sale of water tends to discourage the completion of canals already under way, and prevents the formation of new enterprises, of which our State now stands so much in need. These considerations lead me to the conclusion that so much power ought not to be conferred upon a practically irresponsible body of men as is conferred upon the county commissioners by this act. The law is premature. The danger has not arisen. I have examined the present law. It contains the fun-

damental principles that underlie a good irrigation scheme, and when the time for elaboration of details arrives I am fully convinced that a legislature with wisdom and discretion equal to the task will also appear in view.

Respectfully,

NORMAN B. WILLEY,
Governor.

In Arizona, during 1891, a constitutional convention met at Phœnix, the capital of the Territory. The most striking discussion during its session was over the article on water rights. Propositions to the number of six were introduced. They all united in declaring that the natural waters of the proposed State belonged to the people, were the property of the State, or were held by the legislature thereof for the use and benefit of the public. Riparian rights were denied by all. The legislature was to be given power to supervise and control the distribution of water. The two points at issue were, first, whether by the terms of the article the natural waters of the State should be declared to be the property of the public, held by the legislature in trust for their benefit, or the "the property of the State," the mode and manner of acquiring and exercising which should be subject to legislative control; second, whether or no irrigation districts should be formed.

The following article was adopted in open convention September 29, 1891, as the certificate of the secretary of the convention, H. C. Barnard, testifies:

WATER AND WATER RIGHTS.

SEC. 1. All natural streams and lakes within the boundaries of this State, capable of being used for the purposes of navigation or irrigation, are hereby declared to be the property of the State.

SEC. 2. The common law doctrine of riparian water rights shall never be applied in this State, nor shall the right to use water heretofore lawfully appropriated to beneficial uses ever be denied.

SEC. 3. The right of the people to appropriate and use the unappropriated waters of this State for beneficial purposes shall never be denied; priority of appropriation shall give the better right.

SEC. 4. The right of individuals or corporations to construct reservoirs and impound and appropriate the surplus and flood waters in this State, for sale, rental, domestic, stock, or any beneficial purpose, shall never be denied. The first locator of a reservoir right shall have priority. A failure to construct reservoirs and canals within a reasonable time after location, and a failure to use reasonable diligence to maintain the same so as to supply water, shall be held to work a forfeiture of such rights.

SEC. 5. Every appropriator of water shall use the same reasonably and economically.

SEC. 6. The mode and manner of acquiring and exercising all of said rights shall be subject to legislative control.

AMENDMENT BY COMMITTEE.

SEC. 7. The legislature shall have power to authorize the organization of irrigation districts, and the creation of a debt, for the construction or purchase of reservoirs, dams, canals and ditches, and other appliances required to supply water to lands in said districts. But such debt, principal, and interest shall subject only the lands benefited or reclaimed to taxation to pay the same—

SEC.—. The legislature shall pass laws requiring the owner or owners of every ditch or canal from which water is rented or sold to other parties, to use reasonable diligence in keeping such ditch or canal in such condition and repair as to supply the water required.

The constitution, with this article in it, was ratified by a majority of 3,000 at an election held on the first Tuesday in December, 1891. The discussion in the press and before the people was quite exhaustive, it being charged that, by the article adopted by the convention and popular vote, to the State as a corporate body was given the ownership of the natural waters; that the legislature was empowered to dispose of them and to permit their sale or rental for "beneficial purposes;" that it had no power to prevent access to any body of natural water by any corporation or parties seeking their appropriation for sale and profit; and that said provisions were contrary to the principles found in Spanish and Mexican law, upon which the territorial code had been founded, and the provisions were altogether at variance with the general policy of States like Colorado, which makes water natural wealth and the property of the public, while providing that the legislature shall only be the trustee and conserver, and not the owner or seller thereof. The irrigating ranchmen and farmers of Arizona took a contrary view to these criticisms, while the district provision met with general favor on both sides.

The State legislature of Kansas passed, at its last session, 1891, an elaborate code of legal regulations for the government and distribution of water supply within the semiarid portion of that State. It is probably the most direct, simple, and even drastic system of State and municipal control and supervision, which has yet been legislatively adopted. It provides for the organization of municipal irrigation districts with power to issue bonds for works not to exceed in amount $1 per acre of the area embraced. It also provided for tribunals to settle water disputes and contains other provisions of importance. One district in Finney County, embracing Garden City and adjacent portions of the Arkansas Valley, has already been organized. This bill was framed and submitted to the legislature by Judge J. W. Gregory, of Garden City, who has served the Department in the artesian and underflow investigation. Its main features as drafted by him were adopted.

The operations under the Melville irrigation act in South Dakota bid fair to prove as useful to that State in its degree as the Wright code of laws has in California. It provides that upon petition of at least twenty property owners within a township, the State irrigation engineer shall examine the township for sites for artesian wells. If the engineer approves, the township may issue bonds to pay the cost of constructing not more than nine 6 inch or sixteen 4-inch wells, located by the engineer with a view to their success as wells and their availability for irrigating the lands of the township.

During the year 1891 State Irrigation Engineer J. H. Baldwin located one hundred and fifty well sites, and the number may be increased before his official report is made to the State legislature. The limitation of the townships to the issue of but 5 per cent of their assessed valuation in the matter of artesian-well bonds has given a market stability, which, combined with the assured success of irrigation by means of artesian water, has made this legislation a success.

During the year the State legislature of Colorado adopted laws which were approved by the governor, providing for the encouragement of water storage by means of reservoirs. These methods of storage are multiplying very rapidly, and the legislation proposed seeks to define the legal methods by which the people owning them may be able to use the same without infringing upon the rights of others. Another bill was introduced to define the phrase "water for domestic purposes," as used in the State constitution. This is a subject very much in controversy in that State. Under the bill introduced it was provided that the phrase shall not be so interpreted as to include water for the irrigation of land or plants in any manner or to any extent whatever. Water intended only for domestic purposes is not to be carried for irrigation ditches or conduits, where the loss by seepage, breakage, or evaporation exceeds 2 per cent of the water so carried. Whether this bill became law the office is not informed. Two decisions have recently been made by a district judge, in which the old irrigation settlements of Greeley and neighborhood are greatly interested.

This case has been decided by the judge in favor of the landowner on which an irrigation pump had been operated. It was charged that the water lifted by the pump was the product of seepage from a neighboring ditch. The ditch, however, was not a party to the suit. The persons suing were appropriators of water from a small creek on the other side of the pumped land from the ditch. It was alleged that the ditch seepage had increased the flow of the creek and that upon such increased flow the appropriation in 1886 had been made. When the pumps were in operation upon the land lying between the creek and the ditch the allegation is that the flow almost ceased in the creek. Action was brought to enjoin the further use of the pumps. The judge's instructions were in substance as follows: That water percolating beneath the soil (in no well defined channel) belongs to the owner of the land and he is privileged to use the same as he thinks best. This is the first time that the question has arisen in Colorado and, so far as knowledge now goes, in any of the States requiring irrigation for reclamation purposes. It is quite probable that in Colorado the decision, if sustained by the Supreme Court, will give great impulse to the use of pumps in lifting the gravel-drainage and other phreatic waters. A clause in the irrigation laws of that State, conveys to the man who will develop or bring to the surface of his own land all the water which he may find underneath the same. This much is certain, that, in the interpretation given by the judge and sustained by the jury, the application will most certainly be at variance with the codes and practices of older and more ancient irrigation communities. The general principle of Spanish, Moorish, Indian, and Asiatic law on this subject is, that underground waters developed by a land owner are the property of that person, subject to the condition that the water rights of other persons are not injured thereby. It is quite within the power of persons using pumps to place the same in such close contact with a reservoir or ditch, as actually to drain the waters thereof. A clearer comprehension of the equities underlying such a question as this may soon produce a modification of the decision given.

Another decision by the same court embodies the principle embraced in the contention that a public irrigation canal is a common carrier. It also embodies the conception that the beneficial uses to which water is to be applied must not be hindered or prevented by the action of the canal companies. The plaintiffs in the suit were the owners of a certain reservoir constructed by themselves as farmers. They were also the owners of certain or all of the water rights in a connected ditch. During the last summer their crops being in danger, they desired to run water from the reservoir through the ditch, but were refused by the parties owning the same. An order was given in court granting the right to run the reservoir water through the said canal. An injunction was obtained in a Denver court forbidding this action. This was afterwards dissolved by the same judge. Suit was then entered in the Greeley court, and damages to the extent of $1,200 were obtained. It is alleged that the exercise of this power would interfere with the duties of the ditch as a common carrier, as all head gates along the route would have to be shut down while the water was running. The probability is that this objection was a legal fiction in the case under consideration, as it is understood that the plaintiffs were all the patrons of the ditch in question, but the presentation of such points show the importance of the issues that arise and the legal principles involved. The courts in Colorado are especially involved and loaded with cases connected with irrigation and water conservation and distribution. More and more the necessity will arise for simplifying legal enactments and placing the control of water and works nearer to and more directly in the hands of the people affected by and interested in them.

The following dates and titles refer to the irrigation legislation of the past year in the States and Territories named:

[*California.*—(State Laws, pp. 46, 127, 128, 211, 229, 247) March 1, 20, 31, 1891.]

Regulation—Election of boards of directors of irrigation districts.
Assessments for improvements, irrigation districts.
Board of railroad commissioners to have same powers in relation to irrigation companies as in relation to railroad companies.
Reclamation of lands—Powers of trustees of districts.
Reclamation of districts, unpaid assessments payable in installments.
Organization and government of levee districts, to confine innavigable running streams to fixed channels.
Land and water corporations may divide property among stockholders.

[*Colorado.*—(S. L., pp. 96, 97, 385, 402) March 19; April 1, 2, 1891.]

Reservoirs—Construction by ditch companies.
Ditch and reservoir companies may extend term of incorporation.
Water appropriated for domestic purposes shall not be used for irrigation.
Water rights and lands—towns and cities may purchase.

[*Kansas.*—(S. L., p. 133) March 10, 1891.]

Creation of irrigation districts.
Diversion and appropriation of water for industrial uses.
Rate of charges for water purchased from irrigation companies.
Disposal of seepage waters.
Artesian wells—regulation.

[*Montana.*—(S. L., p. 295) March 6, 1891.]

Mode of obtaining right of way.

[*New Mexico.*—(Territorial Laws, pp. 54, 71) February 24, 26, 1891.]

Water—Appropriation for ditches, canals, or feeders of reservoirs. Filing statement of work necessary to secure priority of right.
County commissioners to furnish tools, work to be done by citizens.

[*Nevada.*—(S. L., p. 92) March 23, 1891.]

Irrigation districts, organization and government.

[*North Dakota.*—(S. L., pp. 33, 34, 75) March 6, 7, 11, 1891.]

Irrigation, formation of districts, regulation.
Creating office of State superintendent of irrigation and forestry—duties.
Sinking by townships for public purposes, issue of bonds therefor.
To encourage construction by private parties and corporations.

[*Oregon.*—(S. L., pp. 52, 74) February 18, 20, 1891.]

Appropriation of water for irrigation and other purposes.
Irrigating ditches.
Punishment for obstructing streams.

[*Washington.*—(S. L., pp. 60, 142) March 2, 9, 1891.]

Appropriation of water for irrigation, mining, manufacturing, or public water works.
Cutting or breaking of dikes or dams.

[*Wyoming.*—(S. L., pp. 8, 88) December 22, 1890; January 10, 1891.]

Water districts—Constitution and government of.
Water commissioners—Appointment and duties of.
Ditch and water companies may issue bonds or mortgage property.

MUNICIPAL CONTROL OF IRRIGATION WATER AND WORKS.

The irrigation districts of California still continue to hold, in the discussion of administrative organization methods, the largest place. The following table, corrected up to November, 1891, will be of value in this connection. It gives a list of the fully organized districts (now thirty-two in number), their location, the names and post-office addresses of the secretaries, the acreage embraced in each district, the amount of bonds voted and sold, and the amount per acre for which the irrigator will be liable in each instance.

Irrigation districts in California, 1891.

Name of district.	County.	Secretary.	Address.	No. of acres.	Confirmed.	Bonds voted.	Bonds sold.	Bonds per acre.
Alessandro	San Bernardino	George H. Kelsey	Moreno, Cal	25,500	Yes.	$765,000	765,000	$30.00
Citrus Belt	do	C. C. Woodroof	Colton, Cal	11,700	Yes.	800,000	800,000	68.37
East Riverside	do	J. A. Vanarsdale	do	3,600	Yes.	250,000	100,000	83.33
Grapeland	do	E. T. Myers	Grapeland, Cal	10,787	Yes.	200,000	None.	18.54
Rialto	do	Devillo Robinson	Colton, Cal	7,200	Yes.	500,000	500,000	69.44
Box Spring	do	....	....	41,000	No.	Not st'd.	Not st'd.	....
Elsinore	San Diego	D. F. Pierce	Elsinore, Cal	11,300	Yes.	452,000	(a)	40.00
Linda Vista	do	....	....	42,000	No.	None.	None.	....
Jamacha	do	....	....	22,000	Yes.	Not st'd.	b25,000	....
Otay	do	....	....	60,000	No.	None.	None.	....
San Marcos	do	....	....	40,000	Yes.	350,000	c350,000	9.45
Alessandro	do	....	....	25,000	Yes.	765,000	a765,000	30.65
Escondido	do	A. J. Werden	Escondido, Cal	12,800	Yes.	450,000	(a)	35,12
Fallbrook	do	G. A. Scott	Fallbrook, Cal	12,000	No.	400,000	(a)	....
Murrieta	do	J. C. Mason	Murrieta, Cal	15,600	No.	None.	None.	33.33
Perris	do	H. A. Plimpton	Perris, Cal	22,800	Yes.	442,000	a252,000	19.48
San Jacinto and Pleasant Valley	do	....	Winchester, Cal	19,700	No.	None.	None.	....
Spring Valley	do	....	....	22,000	No.	None.	None.	....
Big Rock Creek	Los Angeles	L. C. Tilghman	Llano, Cal	40,000	Yes.	400,000	400,000	10.00
Pomona Orange Belt	do	F. P. Firey	Pomona, Cal	4,500	*Yes.	200,000	None.	44.44
Palmdale	do	....	....	....	No.	....	....	....
Vineland	do	I. N. Rhodes	Vineland, Cal	4,500	No.	50,000	50,000	11.11
Santa Gertrudes	do	F. McCarie	Santa Fé Springs	2,600	No.	None.	None.	....
Anaheim	Orange	B. V. Garwood	Anaheim, Cal	32,500	†Yes.	600,000	200,000	18.46
Orland South Side	Colusa	T. H. Dawson	Orland, Cal	25,000	Yes.	None.	None.	....
Central	do	R. DeLappe	Maxwell, Cal	156,550	Yes.	750,000	480,000	4.78
Kraft	do	J. W. Rogers	Orland, Cal	13,500	Yes.	80,000	None.	5.93
Colusa	do	....	....	100,000	No.	600,000	None.	6.00
Tulare	Tulare	E. Oakford	Tulare, Cal	36,700	Yes.	500,000	150,000	13.61
Tule River	do	....	....	18,000	No.	Not st'd.	Not st'd.	....
Poso	Kern	J. E. Anderson	Spottiswood, Cal	40,000	Yes.	500,000	250,000	12.50
Kern and Tulare	Kern and Tulare	J. O. Sidener	Delano, Cal	84,335	‡Yes.	700,000	350,000	8.60
Madera	Fresno	E. H. Cox	Madera, Cal	305,000	Yes.	850,000	None.	2.78
Alta	Fresno and Tulare	George H. Weaver	Dinuba, Cal	129,927	Yes.	675,000	416,000	5.19
Sunset	do	M. McWhorter	Selma, Cal	363,400	No.	2,000,000	None.	5.50
Selma	do	W. L. Chappell	do	271,000	No.	None.	None.	....
Modesto	Stanislaus	C. S. Abbott	Modesto, Cal	81,500	Yes.	800,000	142,000	9.81
Turlock	Stanislaus and Merced	R. M. Williams	Ceres, Cal	176,210	Yes.	600,000	422,500	3.40
Browns Valley	Yuba	John McFarlane	Browns Valley	43,000	No.	100,000	100,000	2.56
Happy Valley	Shasta	....	....	18,000	No.	None.	None.	....
Total	....	....	....	2,412,215	....	14,787,000	652,500	‡20.80

* Confirmation of bonds denied.

† Bond issue declared illegal.

‡ Average cost per acre on 29 districts that are among the most costly in California. This figure represents, however, a 20 years purchase.

a These districts are now being, or will be furnished water from the Bear Valley system of reservoirs.

b Works of a private corporation have been purchased.

c Negotiating with Eastern construction company for sale of bonds.

It will be observed that twenty-four of these organized districts are located in the four southern counties; that one is in Fresno County, two in Tulare; three jointly in that county and Tulare; one in Kern, and one in Kern and Tulare; with one, the Turlock, in Stanislaus County, and one in Merced County (the Modesto); the San Joaquin Valley has 11 of these organizations. Colusa County, in the Sacramento Valley, northern California, has three districts, and Yuba, a lower Sacramento county, has the remaining one. Up to the date of this table, twenty-four districts have been confirmed by the courts. The bonds of only one district have been declared illegal. Thirteen of the thirty-nine named in the table are still in process of organization. The voters of the Sunset district have rejected the proposition for an issue of bonds.

The State Association of Irrigation Districts have succeeded in securing the favorable support of San Francisco banks in the work of negotiating the bonds of the several districts. The State Board of Trade asked for a special investigation of the district system by the Department, and the Irrigation Congress which assembled at Salt Lake City in September, 1891, also indorsed the system. Under a later date than the table given, from report made at a meeting of the State Association, it is learned that the Vineland district, Los Angeles County, had successfully disposed of $50,000 in bonds. The district is small, containing only 4,500 acres, and is devoted wholly to fruit growing. A tunnel of 300 feet has been made and 15 miles of vitrified clay pipe has been laid. The Anaheim district has sold its bonds to the amount of $200,000. In the orange district, not given in the table, the water needed has been bought with bonds at par. East Riverside (embracing the Gage wells and canal system) has been successfully organized and all the bonds are sold or taken in exchange for a water supply. No other particulars received. The Browns Valley district, Yuba County, has sold $120,000 of its bonds, the full issue. Pasadena, the well-known fruit-growing community of Los Angeles, has also decided to form a district organization, and steps to that end have been taken. The consensus of opinion throughout California is strongly favorable to this policy. Engineer Grunsky, of San Francisco, expresses this opinion when he says in a paper sent to this office, that—

> The advantage of vesting ownership and control of canals upon which landowners must rely for their supply of irrigation water in the landowners or rather in the land itself, received a proper recognition when the law authorizing the formation of irrigation districts was passed four years ago. District after district has been formed under this law until there are now about thirty duly organized in this State. Some of these districts by reason of the purchase of canals already in successful operation are now gradually developing sets of rules and regulations for the distribution and use of water, others are rapidly carrying their works forward to completion, but most of them have barely commenced construction of works.

As already stated the California method has made its way into other States. There are three districts formed in Washington, and one in Kansas, under recent legislation of those States. In South Dakota over one hundred artesian wells districts (township) have been formed. There is some question as to the bonds under the Dakota law, which however will probably be cured by the next State legislature.

OPPOSITION TO THE SYSTEM.

The progress of the California irrigation district system is a matter which materially concerns all of the communities interested in the management of water for the purpose of cultivating the soil. A considerable controversy has arisen, and various charges have been made as to the failure of certain districts to furnish a proper supply to their resident irrigators, and also intimating extravagance and corruption in the management of other districts. This office, in consideration of the policy involved in the progress of the California system, endeavored to ascertain the truth of the criticism of the charges made. Without partisanship it is easy to perceive that well-established canal and irrigation companies having large areas prosperous in condition tributary to their systems would naturally be opposed to any change which would destroy their organization. The opposition this would make must of necessity be powerful when the company interests is strengthened by the objection of the cultivators under their ditches to any change in the system. In the great raisin-growing region about Fresno this feeling on the part of canal owners and irrigators is very marked. Outside of the vineyard section there are in that county great tracts of land owned by single individuals or combinations of persons and held largely uncultivated for the market rise. A natural consequence of such a condition is the efforts of the more intelligent irrigator, who may own but a small farm, to secure the advantages which association produces under the Wright district system. Following the lines of this interesting movement a controversy relating to the Selma irrigation district was noticed as proceeding in the press. Correspondence had with leading men shows that the proposed district is now irrigated by a system of ditches belonging to a private corporation. The issue of bonds for the purchase or construction of works was decided at a district election, and a majority of 119 votes were cast against the proposition. It is alleged on the one hand that the corporation actively worked to secure the defeat; on the other hand it is asserted that the majority of those voting were content with the service furnished by the private company. All sorts of statements were made during the canvass. The Alta irrigation district, on the other side of Kings River from Selma, is one of the oldest formed under the Wright code. Against its administration accusations were made that the cost of irrigation was $5.75 per acre for the last season and that only 10,750 acres were watered. Mr. C. C. Wright, author of the laws and attorney for the district, in reply to a letter, pronounces the statements to be without foundation. Mr. Wright says:

> When the Alta district was formed there ran through it a large canal (then the largest in the State), and as its location was of the most favorable character it was purchased by the district at a cost of $410,000. This purchase was made on the 1st day of July, 1890. Since that time the board of directors have diligently prosecuted the work of completing the distributing branches, and as a result almost all of the land in the district is within easy access of the water for irrigation. The work of distribution is not entirely completed but is mainly done and is practically at an end. There is no reason why every farmer may not have all the water he may need for irrigation at the coming season. The pay roll of the district during this constructive period has been very large and expenses correspondingly heavy. But the work which has been done will never have to be repeated, and if every acre in the district were actually irrigated the cost would be but a trifle more than the expense which had to be met during the last season. The engineer most familiar with the situation estimates that a further expenditure of $65,000 will complete the system. The interest on this last-named amount at 6 per cent per annum would be $3,900, and this represents the additional amount which would have to be raised on interest account above what was raised for last year. The expense of officering the district would not be materially more if every acre in it were actually irrigated. If the system is completed and every one may have water by applying for it, the cost of supply should be determined in dividing the total acreage by the total expense, and that will give the average cost per acre. The levy for 1891 (covering interest fund and general expense fund) will raise something over $55,000, and this sum, divided by the total acreage, 130,000 acres, gives an average cost of something over 40 cents per acre. Before the district

was organized the corporation which owned the canal furnished water on the following terms: $10 per acre for a water right and a further charge of $1 per annum per acre for supplying the water. Counting interest at the rate of 10 per cent per annum (a rate which would have to be paid for small loans in the part of the State where this district is situated), the annual cost of irrigating each acre before the district was organized was $2. You can easily arrive at a fair estimate of the cost of this district irrigation with these figures before you. They have expended $410,000 for the main canal and the estimate of finishing the system is $65,000 more. This limit will enable the board of directors to cancel $200,000 of the bonds voted by the people for the perfection of a system. That is not very disappointing to the people I would say. By consulting the law one will be able to arrive at an approximately correct estimate of the current expense of running the district. The board of directors are required to meet at least once a month. When the system is completed they would not meet oftener. For one meeting each director would get $4 and mileage to the place of meeting from his residence. The other officers get such compensation as the board may fix, provided that the people of the district can vote a salary schedule at any regular election.

Mr. Wright states of other district matters in the valley of the San Joaquin that the Sunset district, as it is termed, to the west of Fresno, and comprising a very large portion of the comparatively low tableland region which make up the eastern slope of the Coast Range, is now engaged in making the permanent surveys necessary for the competitive plans they will need in order to carry on their system. The usual preliminary court proceedings necessary to establish the legitimacy and legal character of their organization have been successfully carried through the courts. The establishment of this district, if successful, will open up a great range of fertile country now entirely given over to very sparsely occupied sheep and cattle ranches.

A section profile of the San Joaquin Valley, passing through Fresno City as a central point and following the mountains to their summits on either side of the valley, will reach the summit of the Sierra Nevada at or near Mount Whitney on the east. On the west it will pass just north of San Carlos on the famous Panoche Grande grant. On the extreme eastern point the elevation will be over 14,000 feet, on the extreme western end it will be about 6,000 feet. In the center, a few miles west of Fresno City, the valley will be at or near sea level. On the eastern range the precipitation at the highest point will be not less than 75 or 80 inches per annum. On the western it will be from 28 to 35. At the lowest point in the valley it will not exceed 7 inches. Nearly all of the streams from which an irrigation supply is derived for the San Joaquin Valley, head in the Sierra Nevada Range, finding their sources at the base or on the sides of Mount Whitney. The streams of the Coast Range run toward the Pacific. As a result of these topographical conditions, the western side of the lower San Joaquin Valley has been deemed too arid to be utilized for irrigation purposes. The plan of the Sunset district managers involves the carrying of a water supply from the east side by means of a costly flume across the lowest portion of the great valley. It is this situation that gives such importance to their enterprise. The development of a water supply upon the Coast Range is too hazardous a plan to be undertaken at present, and so it becomes more practicable to furnish the same from the surplus of the eastern streams. Great prizes, commercially speaking, are presented to the minds of men of organizing and speculative character in that region by the possibility still before them of obtaining a profitable control of the surplus and storm waters of streams like the King River. Doubtless this possibility adds a great deal to the tenacity with which the district system has been fought. The recent decision of the Supreme Court as to the legality of the Madera district, also a part of this great valley, is one of magnitude in its possible effect upon the system of large landowning and of water monopoly. The Madera district has an area of 330,000 acres, and under present circumstances more than one-third of the land is under the control of six owners; while the entire acreage irrigated as to water is tributary to two or three companies.

The great canal and other works in the Modesto and Turlock districts are reported by Mr. Wright to be proceeding with considerable rapidity. He says:

> The great dam above La Grange will probably be completed within six months or less time (November, 1891). They have got high enough now to be independent of the rises of the winter and the work will go on without interruption until completed. The entire cost of construction in Modesto district will fall $200,000 below the amount provided for in the bond issue, while in Turlock district it will exceed the estimate by about the same figure. We expect that both of these districts will be supplied with water in time for the spring of 1893, or about one year from this date. This means that more than one-quarter million acres will be redeemed in these two districts alone.

The valley of the Upper Sacramento is one of the great wheat-growing regions of the State of California. In the valley the farms assume the character of large plantations. The smallest seldom ranges below 500 and then run up all the way to 40,000 acres. During the summer work of the special agent he drove over a portion of Colusa County for the purpose of examining the extensive works of the central irrigation district. The wheat harvest was in progress of reaping and gathering, as was the case also in Stanislaus County. It was a remarkable sight to see the great double-header machines drawn by from 24 to 36 mules and attended by from 5 to 10 men, making swaths often a mile in length, reaping, thrashing, and sacking the grain while in progress. The enormous areas of golden grain, ripening in the unblinking sunlight beneath the cloudless skies of central California, almost unvocal of human voices, with scarcely a dwelling in sight, and nothing to be seen but the monstrous machinery, and the enormous area of unfenced grain, was indeed a striking spectacle. One could but sympathize with the bitter remark of a prominent public man with whom the journey in Stanislaus County was made, as we looked upon the huge machine in operation: "I want men, not things, to inhabit this country. That is why I am for irrigation." In Colusa County, the center of the Sacremento Valley during the last decade, according to the United States census, the average size of the holding of land to each individual owner has increased considerably. The farm inhabitants have lessened in numbers.

The foothill sections on either side of this valley are held in farms of moderate size, though much larger than the average fruit-holdings in Southern California. The farmers have been working down from the foothills into the valley and find themselves almost inevitably arrayed against the greater land-owning interest. The orchard is a profitable feature of the foothills region and the commercial value of California fruit is stimulating great horticultural activity. This again creates a demand for the advantages embodied in the irrigation district system. As a consequence of the feeling on that subject three districts have been formed in Colusa County. The majority of votes cast in favor of this action by no means represents the majority of acres embraced. That fact probably accounts for the assertive vigor of the anti-district irrigation feeling. It is asserted that the cost of the great works now being constructed in the Central district will be so much larger than the official estimate as to result in the practical bankruptcy of the people interested. Mr. Wright, the attorney for the district, states that—

> The people first voted, I believe, $750,000 in bonds. If $200,000 more are required it will still leave the cost at less than $6 per acre. This cost per acre would be just what the people of Alta district paid for three years' water before the district was formed.

C. E. Grunsky, the civil engineer in charge of the works, says, under date of December 1, 1891:

> The cost of our work as compared with the original estimates, which were of a general nature and made before the plans of work were fully matured, is clearly and correctly set forth in W. H. Hall's report on the district. It is a fact that right of way has in some instances cost an excessive amount, but in submitting my original report I stated to the board of directors that I had not included right of way in my estimate because I was not then sufficiently familiar with public sentiment in the district to know at what value to figure the lands and privileges to be condemned. Excessive cost of right of way can therefore only be compared with an indefinite general estimate of its value as originally fixed by the board.
>
> It is clearly shown that a further issue of bonds will be necessary to complete the district works. No new contracts have been awarded since Mr. Hall's report was written and work for this season has been suspended.

Mr. William Ham. Hall, C. E., in a report on the district under consideration, states:

> At this day over 140,000 of its 156,540 acres are in tillage for cereals. Fruits and vines are in a small way and locally grown, and alfalfa in especially favored localities, where water can be cheaply pumped. There are probably not over a couple of thousand acres in the district which have not been in tillage for a number of years.

Wheat-growing is not profitable for small landowners. In the Central district of Colusa, according to Mr. Hall, there are 40 owners of over 1,000 acres each, with an aggregate among them of 89,000 acres or more than half the area of the district. The whole district contains but 180 owners of farming land. On these lands and outside two small towns there are but 260 voters—that is, 1.06 voters to the square mile. Ordinarily this would make five persons on that area, but as a considerable number are laborers and unmarried, the permanent population is very small indeed. A very large proportion of the landowners are not residents of the districts, and some of them not even of the State or nation. The upper Sacramento Valley has not until recently been discussed for irrigation purposes, but the former State engineer declares that the area is admirably adapted for farming by irrigation and small holdings. He gives the following succinct account of the system:

> As planned by the district chief engineer (Mr. Grunsky) the Central district irrigation works will consist of (1) a main canal, 61.35 miles in length, having in successive divisions 60, 55, 50, and so on down to 25 feet of bottom width, with side slopes of 1 in 1½, and to carry 6 feet depth of water throughout on a uniform gradient of 1 in 1,000; and (2) 199 miles of distributary canals and ditches, varying in width from 8 to 20 feet on the bottom, and to carry water from 2 to 4 feet in depth on the slopes of the country generally across the district, as modified by occasional check weirs and drops to be built in these water ways. These canals and ditches are expected to distribute water to the highest point of each section (640 acres) of land.

The charge has been made by the opposition to the district that the total cost will not be less than $2,000,000; the estimated cost is $940,354. There remains of this sum to be contracted for, $304,602. Engineer Hall's statement—and from his position as the engineer adviser of bankers engaged in disposing of irrigation bonds, it must be deemed very conservative—is that the work can be put in good running order, and the 10 per cent discount on the sale of bonds be allowed on a total issue in bonds of $1,000,000, or a field and construction cost of $945,000. As the original amount of bond issue was $750,000, this leaves $250,000 to be raised for completing the works. The assessed value of farming lands in the central district for the year 1890–'91 was $2,188,278, making a mean valuation per acre of $13.97. The best farming lands in that district will sell for an average of about $55 per acre. It is the opinion of Mr. Hall that the completion and operation of the canal system in the central district of Colusa will, within five years thereafter, double the value of every acre of land. He estimates the present market or mortgage value of the whole acreage at $4,500,000. As a business operation the bonded indebtedness to complete this irrigation system when charged entirely against the farming lands will make a debt rating at $\$6.42\frac{9}{10}$ per acre. The valuation under the tax levy is now $13.97. For mortgage purposes the average value of the acre would be $30. Doubling that figure and taking five years for the period of increase the rate will be 20 per cent per annum or dollar for dollar at the end of that time.

These instances have been referred to, first, because of the controversy in the California press, and second, because of the light they shed on the questions involved pro and con in connection with the organization of municipal districts for the purpose of constructing works and administering a water supply to be used in the cultivation of land by irrigation. Many grave matters are embraced within such a discussion.

FRUIT CULTURE BY IRRIGATION.

The California State Board of Trade, on September 8, 1891, authorized the statement that 2,075 carloads of fruit had been shipped East as against 1,750 carloads for the same date last year. It is interesting to note that the shipments of vegetables for last year according to the same authority was 2,492 carloads of 10 tons each. This product, which includes potatoes and beans, is of more money value to the State than the entire citrus growth, a fact not very generally known. The maturing of these vegetable products is as a rule at that period of the year when elsewhere, except in Southern seaboard and Gulf States, such production remains a climatic impossibility. The chief shipments of such winter-grown vegetables are from sections of Los Angeles, Orange, and San Bernardino counties favorably affected by natural sub-irrigation. There are considerable areas, especially in Los Angeles County, where the drainage of higher sections, as well also as the irrigation seepage affect the moisture of land lying nearer the coast and at a lower altitude than the more inland section. As a consequence, much of this area has not been placed "under ditch." It produces vigorously, and being almost semi-tropical in climatic conditions, with the favorable facts of winter rains and sub or phreatic moisture, it has developed rapidly as a producer of early vegetables. The returns of the State Board of Trade are in proof. In the course of his inquiry in the several States of the arid region, the special agent found a considerable demand for statistics of horticultural and vegetable products. At present California is at the front, but the rapid growth of fruit culture as stimulated by irrigation, and active profits, is causing the rapid planting of large orchard areas in Colorado, New Mexico, northwest Montana, eastern Washington, and southwestern Idaho. Utah is also a good horticultural field, and western Colorado is rapidly taking a large place. Mr. L. C. McAfee, identified with the enterprises of Haggin & Tevis, in Kern County, Cal., expressed a general desire in the following suggestion made to the special agent. After remarking that he had written the Department on the subject, Mr. McAfee said:

> There is great difficulty in obtaining accurate statistics of fruit and vegetables. The way it presents itself to me is from a commercial standpoint. California is capable of producing fruits and vegetables of almost every kind, and the facilities of

transportation have so increased that the world is our market; therefore we desire to find out what the world is producing and what the world demands. What is most in demand is what we would first desire to raise, and in order to accomplish that object we ought to have accurate statistics of production. For example, a compilation that would show the whole fruit production and consumption of the world, by counties, would cover this desire. There is another thing which such a statistical report would show, and that is, the horticultaral importance and agricultural value of the arid region. If only one acre in four could be reclaimed it would still bring the product of the arid region up to the product of the balance of the country. I think this simple statement is sufficient of itself to show the absolute necessity and superabounding importance that it holds. This land can only be associated with the valley of the Nile, which is the ideal of agricultural production.

The matter of just legislation on the subject of reclamation of arid lands by irrigation is of the gravest importance, and the Agricultural Department ought to be sustained with great liberality, because it is undertaking to advance knowledge on a new and important enterprise, which needs guidance and direction. The irrigator requires consideration even more than the farmers in the humid States, because irrigation requires more intelligence and arrangement. They can not work singly at all; it requires associated effort to do it properly. Irrigation, more than any other branch of our economic life, demands inquiry and experimentation. I am very emphatic on that. I do not say that we want it, but I say that our people as an integral part of the Government demand it. The importance of the enlargement of the powers of the Agricultural Department can be easily understood, because here are 1,000,000,000 acres of land that are practically worthless without irrigation. With it they not merely take stand with other agricultural lands, but far surpass them in their intrinsic value, and it can be put down as an assured fact that these lands will produce grass crops alone of from $100 to $150 per acre, and represent a minimum production of $50,000,000,000 per year.

No better object lesson of the growth of irrigation in California is to be presented than by a glance at the development of the citrus industries. These fruits are now raised for the purpose of commerce from the Southern border of San Diego line to Red Bluff, in Tehama County. Oranges have been raised much farther north, but only as experiments or for ornament in gardens. The six most southerly counties raise the greater part of the product, and so industriously has their staple been advertised that Eastern readers hardly think of southern California in any other light than as a citrus-growing region. In 1870 there were 7,086 lemon trees and 38,991 orange trees in the State of California. The following table from the report of Mr. B. M. Le Long, secretary of the State Board of Horticulture, will show the amount of increase since the general adoption of irrigation:

Counties.	Orange trees.		Lemon trees.	
	Bearing.	Not bearing.	Bearing.	Not bearing.
SOUTHERN.				
Los Angeles	475,726	511,376	47,403	29,524
Orange (estimated)	89,260	51,769	5,097	19,969
San Bernardino	391,656	1,895,544	24,066	155,934
San Diego	20,715	177,311	7,006	58,916
	983,357	2,636,000	83,572	264,343
SOUTHERN COAST AND RANGE.				
Santa Barbara	6,700	37,500	3,750	9,400
San Luis Obispo	1,200	4,600	600	1,950
Ventura	8,614	55,056	4,215	32,512
	16,514	97,156	8,565	43,862
COAST.				
Monterey	75	146	14	....
Santa Clara	920	415	156	175
Santa Cruz	120	96	44	80
San Meteo	126	244	50	....
	1,241	901	264	255

Counties.	Orange trees.		Lemon trees.	
	Bearing.	Not bearing.	Bearing.	Not bearing.
SAN JOAQUIN VALLEY.				
Fresno	1,113	4,828	400	980
Kern	425	852	275	365
Merced	325	625	215	420
Tulare	1,580	1,750	455	1,430
San Joaquin	112	2,640	22	65
	3,555	10,695	1,367	3,260
THE BAY COUNTIES.				
Alameda	722	1,874	525	632
Contra Costa	155	243	118	140
Marin	225	23	16	....
Napa	455	920	378	254
Solano	1,303	2,114	189	215
Sonoma	1,619	1,466	255	840
	4,479	6,530	1,481	2,091
SACRAMENTO VALLEY.				
Colusa	195	6,728	44	54
Lake	125	236	....	....
Sacramento	1,310	12,300	166	976
Sutter	353	3,144	27	125
Yolo	485	856	214	309
Yuba	3,132	18,027	321	....
	5,600	41,291	778	1,464
FOOTHILLS.				
Amador	72	44	34	18
Butte	3,607	116,005	362	1,400
Calaveras	145	85	18	200
El Dorado	108	176	30	265
Mariposa	28	145	18	115
Nevada	100	200	....	....
Placer	6,055	5,480	595	1,300
Stanislaus	1,154	16,642	254	314
Tehama	380	866	104	114
	11,049	139,643	1,450	3,726
NORTHERN.				
Shasta	74	125	44	....

RECAPITULATION.

Southern	983,357	2,636,000	83,572	264,343
Southern coast and range	16,514	97,156	8,565	43,862
Coast range	1,241	901	264	255
San Joaquin Valley	3,555	10,695	1,367	3,260
The bay counties	4,479	6,530	1,481	2,071
Sacramento	5,600	141,291	1,778	1,464
Foothills	11,049	139,643	1,450	3,726
Northern	74	125	44	....
	1,025,869	2,932,841	97,530	318,981

Total number of orange and lemon trees in the State of California, 4,374,721.

It will be observed that the citrus cultivation is largely on the increase, taking previous planting as a basis of calculation, in the southern, coast, and coast-range counties. This is especially so in the foothills counties. A portion of this sub-classification may be disputed, as in the case of Stanislaus County, but for this purpose it is in the main quite accurate enough. The figures and others that might be given offer a warrant for Mr. McAffee's suggestion as to a report on horticulture.

ARID CLIMATOLOGY.

This report gathers considerable utility from the use made in the review of several of the States and Territories, so far as climatology is concerned, of the admirable report "Irrigation and water storage in the arid region" (Fifty-first Congress, second session, Ex. Doc. No. 287). The Chief Signal Officer and former chief of the Weather Service tersely review the meteorological conditions of the arid region and present careful tables of precipitation, etc. His contention is one that appeals to practical common-sense observation and judgment.

"Identical rainfalls do not suggest," he says, "that any industry or pursuit in which rain is an important element would succeed as far as water is concerned equally at either place." This reference is made on the rainfall figures at Pittsburg, Pa., and Julian, San Diego, Cal., at which places the precipitation is, respectively, over 36 and 37 inches per annum. The difference in effects lies in the difference in distribution by precipitation. At Pittsburg the rainfall is fairly felt throughout the year. At Julian for six months the fall ranges from "no trace" to "fifty-five hundredths of an inch." The rainy season at Julian begins in November and ends in April. For irrigation, whether in the Pacific slope or in the Great Plains, or in the intra-mountain basins between the Rockies and the Sierra Nevada, the vital necessity lies in the distribution more than in the quantity of precipitation. In this relation, then, it is well to emphasize by reproduction the facts involved in the following brief tables of precipitation and temperature presented in the "Progress report," 1890, on "Irrigation in the United States" (pp. 128, 129, 130), published for the office of Irrigation Inquiry by the Fifty-first Congress and the Department of Agriculture. The significance of these summary tabulations consists in the evidence they offer of the seasonal distribution of the rain. If a map of the arid region be taken and the stations given be traced thereon by lines of given longitude, it will be seen that the difference between winter and summer rainfalls rise and fall from a line near to or running on the one hundred and seventh meridian of west longitude like regular steps. East of the line given the summer precipitation ranges it will be seen 7.45 inches at Fort Carter, Mont., to 15.88 inches at Fort Sill, Ind. T., on or near the ninety-seventh meridian, while westward from the line of one hundred and seventh longitude it falls 6.64 inches at Prescott, Ariz., to forty hundredths at Fresno, Cal. These deductions are emphasized by the following summarized tables:

	West longitude.	Average annual mean north to south.
East of 107°:	*Degrees.*	*Inches.*
One	97	26.67
Two	102	19.12
Three	105	13.89
Four	107	12.88
West of 107°:		
Five	1,120	12.22
Six	1,170	14.09
Seven	121 to 125	18.00

In the progress report the special agent in charge suggested that in such seasonal divergencies may be found the key to some of the weightier problems presented to the irrigator. The tables of stations, etc., are given as follows:

Mean seasonal rainfall, mean normal (seasonal) temperature, and elevations of stations named, lying within the semiarid and arid region, west of the ninety-seventh meridian of longitude west of Greenwich and east of the Cascade and Coast Ranges, on the Pacific coast.

I.—ON OR NEAR THE NINETY-SEVENTH MERIDIAN.

State.	Station.	Mean rainfall.			Annual average rainfall.	Mean normal temperature.		Elevation above sea level.
		Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.		Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*
North Dakota	Pembina	2.88	13.92	4.40	21.06	....	....	791
Do	Morehead	4.72	14.24	6.28	25.61	....	....	903
South Dakota	Yankton	5.76	15.80	5.80	27.84	23.3	62.4	1,234
Kansas	Concordia	5.32	13.60	5.88	25.58	....	....	1,364
Indian Territory	Fort Sill	6.20	15.88	9.44	32.28	43.3	72.6	1,200
Texas	San Antonio	8.56	12.80	9.92	31.63	55.9	77.2	781

II.—ON OR NEAR THE ONE HUNDRED AND SECOND MERIDIAN.

State.	Station.	Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.	Annual average rainfall.	Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	Elevation above sea level.
North Dakota	Bismarck	4.80	11.12	3.76	19.57	14.6	57.1	1,681
South Dakota	Fort Sully	3.20	10.01	2.14	15.81	....	....	1,600
Nebraska	North Platte	3.44	11.84	3.80	19.11	30.7	62.6	2,841
Colorado	Las Animas	2.56	8.48	2.24	13.46	....	....	3,899
Texas	Abilene	6.00	9.72	6.24	24.78	....	....	1,748
Do	Fort Stockton	2.76	7.96	8.20	20.09	....	....	3,010

III.—ON OR NEAR THE ONE HUNDRED AND FIFTH MERIDIAN.

State.	Station.	Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.	Annual average rainfall.	Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	Elevation above sea level.
Montana	Poplar River	2.08	7.76	2.24	10.79	....	....	2,002
Wyoming	Cheyenne	6.32	6.56	7.84	9.96	29.4	56.0	6,105
Colorado	Denver	4.27	7.04	3.15	14.58	34.2	61.0	5,281
Texas	Fort Davis	1.95	10.45	6.87	17.71	48.2	69.3	4,928

IV.—ON OR NEAR THE ONE HUNDRED AND SEVENTH MERIDIAN.

State.	Station.	Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.	Annual average rainfall.	Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	Elevation above sea level.
Montana	Fort Assinniboine	3.41	9.02	3.12	16.38	19.8	55.9	2,690
Do	Fort Custer	3.24	7.54	2.95	13.64	28.7	59.1	3,040
Colorado	Montrose	2.88	3.48	3.32	9.34	....	....	5,780
New Mexico	Santa Fé	2.49	7.70	4.24	13.94	33.6	59.2	7,026
Texas	El Paso	1.77	5.49	3.61	11.06	49.3	74.4	3,796

V.—ON OR NEAR THE ONE HUNDRED AND TWELFTH MERIDIAN.

State.	Station.	Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.	Annual average rainfall.	Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	Elevation above sea level.
Montana	Helena	.52	5.68	3.92	13.89	25.1	55.3	4,069
Utah	Salt Lake	7.24	3.00	5.48	16.68	34.6	63.6	4,348
Arizona	Prescott	5.88	6.64	4.48	17.06	....	....	5,389
Do	Phœnix	2.40	1.44	3.00	7.38	55.9	78.0	1,120

VI.—ON OR NEAR THE ONE HUNDRED AND SEVENTEENTH MERIDIAN.

State.	Station.	Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.	Annual average rainfall.	Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	Elevation above sea level.
Washington	Spokane Falls	7.52	4.44	7.56	19.08	32.1	58.5	1,909
Idaho	Boisé City	6.24	2.56	4.60	13.47	35.5	61.5	2,750
Nevada	Winnemucca	3.80	1.76	2.92	8.92	....	....	4,340
California	Tehachapi	7.64	.64	2.72	11.04	....	....	3,964

Mean seasonal rainfall, mean normal (seasonal) temperature, etc.—Continued.

VII.—STATIONS NEAR THE ONE HUNDRED AND TWENTY-FIRST TO THE ONE HUNDRED AND TWENTY-FIFTH MERIDIANS.

State.	Station.	Mean rainfall.			Annual average rainfall.	Mean normal temperature.		Elevation above sea level.
		Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.		Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*
Washington	Fort Simcoe	6.72	1.12	2.72	10.61			
Do.	Ellensburg	3.72	1.76	3.44	8.97			
Oregon	Fort Dallas	9.72	2.08	10.12	21.96			350
Do.	Linkville	8.56	3.48	4.92	14.41	36.0	55.2	
California	Berryvale	5.48	1.20	13.00	28.84			
Do.	Red Bluff	17.92	1.60	10.04	25.99	49.9	71.2	342
Do.	Sacramento	8.44	1.56	5.80	19.69	50.1	67.4	65
Do.	Stockton	8.92	.68	4.28	13.91			
Do.	Merced	7.28	.72	3.72	11.75			17
Do.	Fresno	5.36	.40	3.00	8.79			295
Do.	Visalia	6.72	.60	4.00	9.25			348
Do.	Los Angeles	10.92	.68	4.56	16.3	55.7	67.0	371
Do.	San Diego	6.68	.64	3.36	10.26	55.5	64.7	66

While with Lieut. Glassford and other experts, agreement is had on the general proposition that 20 inches are necessary for industrial use there is evidence to show that as low as 15 inches will serve under proper conditions of soil, etc., if the same can be secured when needed. This conclusion will be found sustained as Gen. Greeley states:

> The latest rainfall maps of the United States compiled at the office of the Chief Signal Officer (March) show that there are enormous areas of country in the so-called arid regions where the rainfall exceeds 15 inches (by which isobyetal, or line of equal rainfall, the arid region is, by some, limited), and even very large areas over which the annual precipitation exceeds 20 inches, and in lesser areas 25 inches.

The discussion of evaporation in Gen. Greeley's paper is very interesting as well as of value. A summary of some of the data is given in the annexed table, prepared from the Weather Service monograph (p. 10, 11, 12).

States and localities.	Total amount (cubic measure).	Average depth of possible evaporation.
		Inches.
Arizona	145.9	80
California	170.9	87
Colorado	108.6	60
Nevada	145.8	90
New Mexico	146.2	78
Utah	90.9	68
Sweetwater, Cal		*29.88
Salt Lake†		74.04
Albuquerque		80
Lake George, New South Wales†		46
Caspian Sea†		43

* These figures are for seven months only.

† Salt Lake has a surface of 4,700, Lake George one of 80, and the Caspian Sea a surface area of 80,000 square miles.

The conclusion in part arrived at by Gen. Greeley as to the practicability of storage will bear quoting. He says:

> What has already been said shows, however, that over very extensive sections of the arid regions the heavy rains from which must be derived waste water for irrigat-

ing purposes come at such a period of the year as to render it necessary to keep the water stored for a long time before it can be generally used for irrigating purposes; that such storage occurs in countries and under conditions where evaporation proceeds rapidly and to a degree almost unequaled in any other part of the world; and also, that the violent rainfalls are in such quantities and cover such an area of country that the whole of these waters can not be stored; and that where storage facilities are provided they must be of most durable and solid construction, with such facilities for carrying off waste water as will render the recurrence of calamities similar to the great disaster on the Hassayampa River in Arizona practically impossible.

The ocean "passage winds" are important to our western irrigation crops, but their humid effects are most strongly felt upon the northwest portion of the Pacific coast. The movement across the ocean plane of these winds tends steadily to west by north. As a result of this, the largest share of the aqueous contents of such winds is precipitated upon the comparatively narrow shore plane of Oregon and Washington, giving thereon the greatest recorded rainfall within the United States. The coast line break at Puget Sound acts as a funnel to draw inward a marked share of this oceanic precipitation, and as the continental topography at this point is considerably less in altitude than further south, we see a marked increase of humidity along the western slopes of the northwest Rockies in Washington and Montana. There is also a considerable influence exercised by what are locally termed the "Chinook" winds that, laden with moisture from the sea, are enabled to pass over low portions of the range and modify the winter climate of such intra-mountain settlements as Helena, Mont., and Boisé City, Idaho, as well as by their deposition of moisture to make Idaho's panhandle section and the eastern foothills region of Washington a subhumid area, fertile to a degree, and largely capable of sustaining cultivation without irrigation, though like the largest portion of the Great Plains the artificial use of water in the ripening months will surely increase security and thereby add greatly to the value of industrial life.

The excess of precipitation along the northwest coast is so marked and peculiar as to warrant a brief reference. Take, for illustration, the record of annual precipitation at San Francisco, Cal., and Tatoosh, Wash., at the entrance of Puget Sound; San Francisco, reports 23.80 inches of rainfall; Tatoosh, one of 94.42, a difference of 70.62 inches. The theoretical difference, as figured by the meteorologist's rule, of a certain per cent of moisture absorbed by the passage winds for each mile of ocean surface they traverse, is much less. Tatoosh is set down under the rule given as entitled to 61.97, a difference of 32.45 inches less than the actual rainfall. The theoretical difference between San Francisco and Tatoosh is as 27.29 to 61.97, or 34.68 inches. These figures strongly illustrate the remarkable northwest tendency of the actual rainfall. Doubtless it will aid greatly in explaining glacier action in Alaska by the evidence given of a high precipitation in a region of very low temperature. The "humid constitution" of the southwest passage wind accounts normally for a considerable portion of the peculiar deposition of the ocean moisture; yet the fact that the increase is in proportion to the northern in latitude points to other causes than the one first named. The materials for explanation are scanty, and the meteorologist does not, as yet, offer any. I venture to suggest that the polar influences may possibly have something to do with the cosmic movement of winds which bear moisture to our Pacific coast, and that the aqueous current thus drawn northeastward may hereafter appear as part of the Atlantic humidity to the south and east.

The analytical summary hereafter given of climatic factors within our Cordilleran region shows how the four barometrical "constants" of two "highs" and two "lows" relate themselves, in general terms, to the northwest. When the area of high barometer, which is a "constant" factor in Oregon and Washington weather, overlies that region the center is probably far to seaward, subject to violent perturbation, and produces storms of the cyclonic type. The eastward movement is checked by the Cascade Range and the Rockies, and the result is heavy precipitation, especially in Washington. The eastward "low" beats against the mountain barriers, and the "high," as it rises and crosses them, remains steadfast, though very much desiccated, over the northern plateau and adjacent parts of the Great Basin. The "low" barometrical area generally has its center near the coast, and its influence as to rain is usually spent upon the shore plane southward to San Francisco, very rarely passing beyond that point. It will be observed by this brief outline how favorable all the conditions are for the extreme northwest section, alike for present irrigation and future water storage.

The following condensed table of rainfall is one of the most useful presented by the Weather Service (p. 19), report on Arid Climatology:

Annual rainfall in sections named.

State.	Elevation.	Area in square miles.	Cubic miles of rainfall.	Average depth of rainfall in inches.
Arizona	Sea level to 3,000 feet	38,670	5.3	8.63
	3,000 to 5,000 feet	27,230	6.3	14.56
	5,000 feet and over	47,120	10.7	14.30
	Whole State	113,020	22.3	12.42
California	Sea level to 2,000 feet	82,290	27.9	21.64
	2,000 to 5,000 feet	53,530	18.2	21.66
	5,000 to 7,000 feet	17,334	7.5	27.56
	7,000 feet and over	6,246	2.7	27.75
	Whole State	159,400	56.3	22.56
Colorado	4,000 feet and less	8,778	1.5	11.15
	4,000 to 5,000 feet	18,031	3.2	11.78
	5,000 to 7,000 feet	31,314	6.1	12.74
	7,000 feet and over	45,885	9.2	13.12
	Whole State	104,500	20.0	12.61
Nevada	Less than 5,000 feet	39,750	5.0	7.98
	5,000 to 7,000 feet	57,654	10.7	11.85
	7,000 feet and over	14,590	2.9	12.92
	Whole State	112,000	18.6	10.64
New Mexico	4,000 feet and less	6,996	1.1	10.14
	4,000 to 5,000 feet	34,407	6.1	11.69
	5,000 to 7,000 feet	57,503	12.4	14.13
	7,000 feet and over	22,300	5.6	10.34
	Whole State	121,200	25.2	13.62
Utah	5,000 feet and less	28,615	4.0	9.00
	5,000 to 7,000 feet	35,444	6.5	11.59
	7,000 feet and over	20,441	3.2	6.97
	Whole State	84,500	13.7	10.32

THE AËRATION OF WATER AND IRRIGATION.

With the application of water properly aërated and the opening of the earth by intensive cultivation to the same atmospheric forces, the irrigation farmer must naturally study the crops best adapted to his conditions. Horticulture is a special culture, requiring careful conditions of place, soil, and climate. The general farmer will necessarily take a wide range. The capacity of plants to penetrate the soil deeply, to draw water supplies by capillary attraction, as well as their differing demands for plant food, are all to be considered. The relations of plants also to alkali soils are of very considerable importance. The most valuable crops yet grown in the arid section are the alfalfa, clover, and other leguminous plants; also the sugar and common beets, with other root and tuber varieties. All cereals and small grains generally derive their nourishment from the first 5 or 6 inches of top soil. Hence the rapid growth that is often seen under irrigation, clear skies, and warm weather. It is a matter of constant remark after planting clover or alfalfa, the latter especially, that the land produces finer crops of wheat, oats, or other of the small grains. The secret of this for irrigators is, that leguminous plants require and contain to an appreciable degree less water, while their roots go deeper down in seeking nutriment.

The aëration of water is an almost indispensable condition of successful cultivation by means of irrigation. Atmospheric gases are always present in the soil. Combined with water, they are essential to the processes by which the mineral constituents are dissolved and their useful portions conveyed to the plant roots for sustenance and growth. The importance of atmospheric impregnation can be forcibly realized by recalling the fact that nitrogenous food is essential to plant life; that pure nitrogen, or azote, from which alone by combinations can such food be produced, comprises four-fifths of our atmosphere. All water absorbs air. The more it does so the better it becomes for use in irrigation. Its fertilizing powers increase rapidly by accelerating the direct and indirect absorption of nitrogen and of its various combinations, such as ammonia, phosphoric acid, potash, etc. Water itself is composed of oxygen and hydrogen in the ratio of 100 to 12½ by weight. Common air, according to Silliman, is composed of oxygen and nitrogen in the proportion by weight of 23 of the former and 77 of the latter. At the ordinary temperature water absorbs of air forty-six one-hundredths of its own volume. The rate will be in a liter* of water: Nitrogen, 65.1; oxygen, 34.9.

The enormous value of nitrogenous material has been forcibly illustrated by Dr. Wiley, department chemist, who has said that 80,000,000,000 pounds enter into the creation of one harvest in the United States,† the value of which is not less than $5,000,000,000.

This enormous mass of plant food is chiefly found as nitrates or albuminoids. All nitrogenous food material is converted before assimilation into nitrate acids or nitrates. Such combinations are soluble in water. The waste of such materials is as enormous and significant as the sum of its utility. Dr. Wiley declares that in the production of the cereals the annual total of phosphoric acid taken from the earth is nearly 3,000,000,000 pounds, while the loss of potash is not less than 4,000,000,000 pounds. Vast stores of such material are carried away by stream or river, and washed from the earth by floods. The enormous masses of silt borne by the streams to the ocean are loaded with nitrogen. This waste is almost ceaseless; nature's destructive or remolding forces are constant. They are not hindered, except by the skill, knowledge, and art of man. The essential food of plant life is thus continually diminishing, and without the artificial aids which knowledge alone points out, there is perpetual tendency to waste, disintegration, barrenness, and aridity. Hence it is that whatsoever tends to the preservation of all such materials belongs to the domain of economic conservation. The care and skill which cultivation under irrigation must create and bring into practical operation is a force the importance of which is hardly demonstrable by any known expressions of value at command.

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* 1.0567 quarts, United States measure.

† Address before the New Jersey State Board of Agriculture, 1889.

To let the air into the water for irrigation is equally as important as to admit the air into the soil by efficient and intensive cultivation. Agricultural chemists are divided on the question of direct assimilation of nitrogen by water, either as rainfall or exposed phreatic supplies and bodies. Large quantities of ammonia and nitric acid are always found in rain water.

From a tabulation of the "Average composition of American feeding stuffs," computed and calculated by E. H. Jenkins and A. L. Winton, jr., and published in Experiment Station Record, July, 1891, Vol. 2, No. 12, United States Department of Agriculture, the following average results are obtained as to the average amount of water chemically found in certain food-plant groups:

	Average.	Remarks.
	Per cent.	
Cereal grasses	47.7	Four varieties and 63 analyses.
Other grasses	67.4	Six varieties and 90 analyses.
Legumes, grasses	75.1	Five varieties and 86 analyses.
Tubes, roots, bulbs, and other vegetables	93.7	Fourteen varieties and 104 analyses.

In Johnson's "How Crops Grow" (p. 39, ed. 1890) the following averages are given: Meadow grass, 71; red clover, 80; corn, 82; cabbage, 85; potato tubers, 75; sugar beets, 81; carrots, 86, and turnips 91 per cent.

The careful investigations constantly in progress at Rothamstead, England, shows that the yearly averages range from 54 to 135 per cent. In a gallon of water the ammonia ranged from 17 to 60 per cent, while of nitric acid the amount was 0.86. But these averages are not enough for the demands of agriculture, and land which is not supplied with the necessary quantity is soon exhausted. The nitrates are not only consumed by the plants, but as already shown, they are constantly being washed from the soil. A recent writer in the Noveau Revue discussing the productiveness of the earth declares it to be illimitable if a sufficient amount of nitrogenous material can be applied to the soil, and he further declares that this is entirely within the range of human skill and prevision. In this view then, the power of fixing as well as gathering nitrogen is of the utmost importance.

Professor Atwater, till recently director of Experimental Stations in the Department of Agriculture, in conjunction with such able chemists as Hellriegel, Muntz, Berteloc, and others, believes the weight of testimony supports his view—that nitrogen is absorbed or conveyed by water directly from the atmosphere. Other chemists hold to the view that only a portion of nitrogenous matter is furnished by rainfall, the balance and the more important part being obtained through the direct influence of plant growth itself. In either way, irrigationists can readily perceive the importance of fully aërating their supply of water before distributing the same to the land. It may be suggested that such insistence upon the value of aëration would necessarily affect the value of systems of conveyance of water by pipes or other underground conduits. This is not necessarily correct, as sufficient atmospheric exposure is usually obtained in streams, standing waters, and reservoirs, before conveyance for irrigation actually begins. But it is almost essential that direct underground supplies shall be exposed to the atmosphere before use. Certainly such aërated water will be more valuable for farm purposes. It is doubtless true that artesian and other phreatic waters contain a proportion of nitrogenous material, though potash does not often appear in the analysis, and of phosphoric acid there is no mention made.

The author of "Agricultural Hydraulics," M. J. Charpentier de Cossigny, gives the following interesting presentation of the manner in which "gas in solution in water" relates itself to plant life and the cultivation of the soil by means of irrigation:

> It must be observed that the oxygen and nitrogen not being in combination act separately, according to their affinity for the liquid, so that the water is always found to have absorbed, following the proportions of the atmosphere, more oxygen than nitrogen.
>
> We will investigate the rôle played by these gases introduced by irrigation waters into the cultivable soil. Oxygen is not so much a food for plants as it is one of the principal agents in the the complex phenomena by which the sap is prepared in the depths of the earth. It slowly burns away the organic matter of vegetable or even animal origin mixed with the soil; it transforms little by little the insoluble matter into a humus which is soluble, and which can be easily assimilated by plants. The oxygen, moreover, holds and returns to the soil at need the sulphur found there in the state of sulphates (inoffensive salts), to the exclusion of the sulphurets, especially the sulphuretted hydrogen, which last is frequently the product of putrid decompositions and which is poisonous to plant life. Finally, this same gas—a life-giving agent par excellence—in encountering calcareous or alkaline matter in the soil, causes the azote or nitrate mixed therein to pass into an azotic state. * * *
>
> As yet no experiment has been made determining the exact part played by the water in introducing azote into the soil, and we can only advance arguments in favor of our presumptions. Is this azote finally disengaged into the atmosphere? It would seem probable for that portion corresponding to the water, which is evaporated on the surface of the soil, under the combined action of the sun and winds. But this is only a small portion of the irrigation, for independently of the limited part which sometimes penetrates to great depths in the earth, there is still another important portion which, after having passed through the plant with the running sap, is returned by transpiration to the atmosphere. But vegetables do not exhale any nitrogen. There is reason to believe, then, that the azote found in solution in that portion of the water of which we are speaking must have become fixed there, either by the soil a little in advance of the penetration of the water into the plants through the roots or else by the plants themselves during the passage of the water through them. In the first case it would not have been impossible for a nitrification of the azote to have occurred, owing to the action of the oxygen and the alkaline substances contained in the water before its absorption by the plants. A gas dissolved in water is in a veritable state of liquefaction. and the molecules are infinitely more condensed than when they are in a gaseous state, which considerably augments the energy of the physical force. Who has not noticed, for instance, that the action of the air has no effect on iron nor on most other minerals when they are in a dry state, but that it oxidizes them as soon as water is introduced. Would it not also be possible for nitrogen—usually in an inert state—to become a more active principle when in solution?
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> M. Hervé Mangon has experimented upon a prairie by irrigation through a whole season. At each irrigation he has measured the quantity of water appropriated and also the quantity which has afterwards escaped, not having been absorbed. He calculated the quantity of nitrogen furnished to the soil by known agents and the quantity found in the crop itself, and found the last quantity in excess of the first. Whence comes, then, this excess, except from the atmosphere, and through what channels, under what influences, and by what chemical aid does this substance penetrate into the earth? M. Georges has claimed that the azote (nitrogen) is directly absorbed by the leaves, but the truth of this hypothesis has not yet been demonstrated; and it is now generally believed that, through the intermediation of the soil and the roots, azotic matter passes into the organism of the plant.
>
> But water contains in solution not only oxygen and hydrogen, but carbonic acid also in various proportions. But the carbonic acid found in the water could not be accounted for by the quantity found in the atmosphere, without the intervention of other causes; one of these facts is that the water of the springs is more or less mixed with carbonic acid and their water is more or less mingled with that of the rivers themselves. On the other hand, Mangon found that irrigation water running along in narrow channels on the surface of the ground was found to

be much more highly charged with carbonic acid than before its passage over this prairie. Might it not be by means of a similar phenomena, that is produced during heavy rains on the surface of each field, that the waters of a river are much more highly charged with carbonic acid at the time of high water than at low water?

In any case this acid plays a very important rôle in vegetation. It is by means of it that water attacks solid rocks, sand, clay, etc., and extracts from these inert substances the fertilizing principles which are assimilated by the soil and which improve it. Water charged with carbonic acid carries with it, in penetrating the soil, the instrument whereby valuable substances are disengaged from it, such as potash and phosphoric acid, which would not otherwise be found either in the water itself or in the fertilizer applied.

* * * * * * *

We know, of course, that water is indispensable to culture and vegetation. The soil deprived of it entirely would either be reduced to a fine dust, incapable of giving that support to the roots of plants which they require, or would form so compact a mass as would be difficult to work with agricultural tools, and which would be almost impenetrable to the reaching out of fine threads of the roots. Water, moreover, seconded by the atmospheric gases with which the earth is usually impregnated, attacks the mineral constituents of the soil and by dissolving carries away from them the useful principles which are at once appropriated by the plants. Water also serves as a vehicle for the conveyance of all the active properties of the compost, and, in a word, water constitutes the principal part of the sap.

The sap absorbed by the spongioles or suckers of the hairy branches of the roots rises to the green parts of the plants and to the leaves. There it is elaborated, assimilates the carbon taken from the carbonic acid of the atmosphere, is concentrated by a considerable evaporation of water, then, descending, is distributed through the plant, producing a growth of these various organs. We know that this transpiration by which plants lose a portion of the water they contain takes place during the heat of the day, and that it is greatest in proportion as the atmosphere is dryer and the soil most saturated with water. Moreover, this evaporation can never be decreased for any species of plants beyond a certain limit. It becomes, however, enormous under the combined action of the dry wind and sun. Physiologists estimate, approximately, the daily evaporation as being one-half the weight of the plant. Thus, according to this estimate, one hectare of cabbages (4,471 acres) may lose 20,000 kilograms (44,000 pounds) of water during the twelve hours of the day. It is easily understood that the general activity of vegetable functions is in proportion to the abundance of transpiration, but only on condition that the soil is able to support the afflux of sap caused by the incessant consumption of water. As soon as the humidity of the earth becomes insufficient, the current diminishes and the plant remains inactive. It is true that transpiration has also diminished, but it can not be altogether annulled; so that if the quantity of water restored by the soil continues to diminish the plant withers, dries up, and finally dies.

THE NEED OF DRAINAGE.

Dennis C. Crane, secretary of the Union County (N. J.) Board of Agriculture, in 1889, made a report, in which he argues for underdraining and irrigation. He brings up the whole question of water management when referring to the damage done by excessive rains. "There is no way of insuring," he says, "against loss * * * so certain as underdraining. By surface ditches it is only partial and not lasting." Mr. Crane declares that two-thirds of the land in his country requires such drainage. The effect is to not only carry off the surface water, but to warm the land, facilitating the working thereof, keeping the surface from being washed, but it also enables the land to better withstand the effects of drought. The soil's nutrient qualities are retained. Mr. Crane, in connection with the effects of drought, presents this argument in favor of irrigation:

> In a dry season everything everywhere is parched and sickly; then the farmer or gardener wishes he could utilize the abundant supply of water under the surface 20 or 50 feet, or the brook not far off, which is running to waste. Drought can be very much mitigated by deep plowing, thorough cultivation, high manuring and mulching, and the inducing of a rank growth early in the season in order to shade the ground,

These are some of the simple, but not always effective, methods. Moisture has two offices: one to give sap to the plant and the other to make the ground soft, so that the fibrous roots can penetrate and reach out for food. To lose a crop by drought is no small loss, especially if it be garden vegetables, fruit, or even general farm crops. Often from $20 to $100 is spent on an acre for plowing, planting, cultivating, and the use of the ground. The crop, if saved and sold, might yield double the above amounts. In every dry season an extra price is usually realized, so it becomes the farmer to study whether he can not, by irrigation, insure himself against drought.

Irrigation necessitates underdraining, for water can not stand on the surface and stagnate. Irrigation is practiced largely out West and in other countries, and why might it not be adopted here by many farmers and gardeners? Those who have streams of water running through their farms might, by a simple, inexpensive method, raise the water to such a height that it could be led to flow over their fields and in a dry season increase the crop a hundredfold. The saving of one crop would often pay for the original outlay.

Grass, especially, responds generously to such treatment. Many places have basins between small hills that could be made reservoirs and filled with water during the rainy season.

THE RIVER SILT AND ITS VALUE.

The importance to cultivation by irrigation of the silt carried by streams to land where the water is to be distributed is a matter that can not be too vigorously emphasized. All hydraulic engineers and irrigation cultivators, except the professional directors of Anglo-Indian works, are in favor of utilizing the silt for fertilizing purposes. The French authorities, de Cossigny, Mangon, and others, are emphatic in favorable argument and illustration. Professor Lyell, the illustrious geologist, taking the experiments of Everest on the waters of the Ganges as a basis, has calculated that this river bears annually to the Indian Ocean quantities of mud of extraordinary fertility, the weight of which would be equal to six times that of the largest pyramid of Egypt, which is higher than the cathedral spire at Strasburg, and three times the height of Place Vendome column. M. Hervé Mangon says that—

> The mud carried off by the rivers to the sea is either taken from the lands under cultivation or from the surfaces of denuded territories. In the first instance, agriculture, in not arresting this mud, allows a part of its domain to escape, thus losing the most valuable part of its capital; in the second instance, she fails to take possession of that which nature so generously places at her disposal.
>
> The weight of the mud drifted by the Var during one year would form a volume of 12,222,000 cubic meters, which would be sufficient to colmatage more than 6,000 hectares to a thickness of 20 centimeters. A small lateral canal carrying water from the Var, properly planned and carrying only one cubic meter of water per second, could colmatage every year to an average thickness of 50 to 60 centimeters ten hectares of sterile soil, and, consequently, create each year a value of 30,000 to 40,000 francs.
>
> If the weight of the drifted mud be added to the weight of the soluble matter * * * it must be remembered that the Seine carries away, under our eyes and without our noticing it as it were, 2,117,984 tons of solid matter every year, a weight nearly equal to the whole of the merchandise transported over this stream to Paris (Agricultural Hydraulics, M. de Cossigny, Paris, 1889, pp. 27, 28).

The utilization and value of this material is constantly and strenuously insisted upon by all European authorities on irrigation. The works of leading French writers and scientists, Messieurs Cossigny, Poyen, Deville, Mangon, and Buffon, are full of illustrative discussion of this problem. Mr. Hervé Mangon, for example, states that the river Durance, an Alpine stream, largely availed of for agricultural purposes, carries annually with its flood a volume of not less than 11,000,000 cubic meters of silt, the fertilizing power of which is equal to 100,000 tons of stable compost or excellent guano, fertilizers full of nitrogenous qualities. This volume of silt contains as much carbon as would 119,000 acres of forest trees. The Var, carrying to the sea, as M. Mangon estimates, not less than 12,220,000 cubic meters of silt, also bears off in it at least 23,000 tons of azote or nitrogen.

Water carries with it as it flows something of all the mineral substance it touches. Rain dissolves the potash in granitic soils and the phosphates in those of a volcanic character. Care is needed, as it sometimes happens that more mineral matter is thus held in solution than is necessary for the crop. The rule, however, is the other way. River water has been found to contain potash in considerable quantity.

The famous artesian well at Grenelle, France, yields water affected by potash. As an example it may be stated on the authority of M. J. Charpentier de Cossigny (Agricultural Hydraulics, Paris, 1889) that a hectare (247 acres) of land receives in six months, under the French plan of irrigation, about 49,600 cubic feet of water, which contains nitrogenous matter equal to 98 tons of stable compost. At Paris the same authority, quoting Deville, estimates that every 3 quarts or liter of water precipitated, contains at least 43 grains of ammonia. The nitrogenous material that runs to waste is, therefore, enormous. Every drop of water contains it and the poorest of river silt is more than equal in fertilizing qualities to the best of stable compost.

The word "colmatage" is necessarily coming into use in connection with irrigation work and an explanation is in order. It signifies a method of raising lowlands by the deposit thereon of river silt, ooze, or mud, which has long been used in Italy and more recently in France. The Italians call the operations carried on by them on the banks of the Arno, Po, and other rivers, "una colimatu," which means "filling up." Mr. Nadault de Buffon has made a new word, "colmatage," which has already become incorporated in the French language and is now coming into use as a technical phrase among English-speaking experts. The deposit of mud or silt on the same piece of ground very quickly acquires a remarkable consistency, especially if the water be freely applied. This plan may be still further pursued. A piece of ground may be submerged by the muddy waters of a river, letting the water continue to run after depositing the mud, and then repeating this operation several times. A substantial soil will thus be created, which will be susceptible of the highest degree of culture, at the same time raising a low-lying piece of ground and transforming the area subject to frequent inundations into one much better adapted to cultivation. This is what is understood by "colmatage." This process has been suggested as a means of beneficially utilizing the "slickens" or débris of the now abandoned hydraulic gold mines of California. This débris became so injurious to the farmers of the San Joaquin and Sacramento valleys by reason of its being deposited in the sierra river beds and thereby causing overflows, that such placer mining was stopped by law. It is now found that the "slickens" can be flumed onto the low tule or marsh lands and be made valuable by creating new soils and new farms.

By all these processes the intrinsic value of the matter contained in the water courses is, by means of irrigation, placed, in a great part, at the disposal of agriculturists. But after all, the value of the fertilizing matter contained in the water is but a small percentage of the value of irrigation, which consists principally in the marvelous effects of the judiciously combined action of the water and the heat. Water assures the efficacy of manure, so that when the application of a fertilizing substance will not produce a sufficient increase of products to pay for the expense of applying it in an unirrigated soil, as soon as the same soil is irrigated this state of things is changed, and a large interest is realized on the amount expended.

THE INFLUENCE OF LIGHT AND HEAT ON VEGETATION—IMPORTANCE IN IRRIGATION.

This is as important as the absorption of nitrogenous materials. A German chemist and writer, Dr. Hellriegel, declares that the stock of nitrogenous matter "at the disposal of a plant is capable of being assimilated only when a given quantity of heat and light is simultaneously offered." At a point lower than the "optimmum temperature," as Dr. Hellriegel terms it, sluggishness of circulation prevails. With the increase of both factors the energy rises to the life point, which is placed between 64 and 104° F. (20 to 40° C.). Heat up to 122° F. (50° C.) is not destructive, though not as desirable as the lower degree of temperature. Above that point it is considered injurious to highly organized plants. Light operates with similar results. The germinative process goes on best in darkness, following in that of course the lines of all natural action. But the seclusion of light from growing plants prevents the formation of leafgreen (chlorophyl) and of all that aids the decomposition of carbonic or carbon dioxide. The assimilation of light into the leaf cells is absolutely necessary to plant growth. Faint light and persistent cloudiness makes feeble the circulation. This increases in intensity with the rise to "optimmum." All these conditions are found in favorable relations within those sections of the United States where irrigation is needed for security or absolutely required to insure cultivation. The lowest point of field germination as to heat is from 32 to 41° F. (0 to 5° C.). The process of respiration in the plant is the one requiring the least amount of light, but the effective assimilation of carbon, so essential to the health of the plant, requires both heat and light. As the vegetation approaches maturity it requires a large degree of both. So it appears that the quantity or range of mean temperature is the measure of productiveness, water and soil being both considered. With irrigation then the dry, warm air of the arid region bears the palm. Heat, light, and water are prerequisites of successful agriculture when brought to and combined with the soil in appropriate conditions and quantities within the laboratory of the earth. The power of heat transmission combined with the transparency or clearness of the atmosphere which is so remarkable a characteristic of arid regions, is another condition of the highest importance to all plant as well as other life. It is shown that "the diathermancy and transparency of the air are both of the very highest importance to the life existing upon the earth. It is its diathermancy which enables the sun's heat to reach the terrestrial surface for the performance of its marvelous operations. It is its transparency which renders the air the window of the earth, giving man his outlook into space, and admitting the wonderful effects of color and light. If the air were not transparent, all nature would be in a perpetual dense fog."*

The same authority presents some figures which forcibly illustrate atmospheric influences on plant growth. Condensing the phenomena presented, it is found that air has weight, a cubic foot turning the balances at 573.5 grains, while 13 feet respond to one pound in weight. Its particles or atoms are so small as to be invisible even under the microscope. Being in the gaseous state they are compressible, and by a pressure of 15 pounds to the square inch air is reduced to half its previous bulk. It has been established that every time the pressure is doubled, the volume of atmospheric air is halved. This is the reason for rarefication at high altitudes. But heat also expands it at "the rate of $\frac{1}{480}$ part for each degree Fahrenheit. The atmosphere is composed of two gases, which mingle without pressure. "Each is, as it were, a vacuum to the other." Aqueous vapor then rises to and is held in the interspaces in a similar manner, but more may be sustained in suspension in warm than in cold air. There is besides the aqueous vapor "3.36 parts in every 10,000 of carbonic acid gas, and 3.5 to every 10,000,000 of ammonia." Every 1,300,000 tons of carbonic acid produces 377,475 tons of carbon for the air that rests upon every square mile of the earth. Of ammonia 30 pounds are carried down each year by rain to each acre on which it falls. A small quantity of ozone is also formed under the operations of atmospheric phenomena. The barometer rises when the air is overcharged with vapor; when that is condensed the barometer falls and rain is produced. For that reason when warm air drinks up the moisture, it rises rapidly and is carried to an altitude when a change of atmosphere brings about condensation and it falls again. Thus the mountain tops become condensers of moisture. These simple items of physical data are presented only to emphasize the conditions which tend, whenever irrigation is practicable in a region without the industrial mean of precipitation, to make agricultural reclamation by the artificial conservation, conveyance, and distribution of water a process so secure and effective to captivate the brain and energies of all who pursue its practice.

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* Scientific American Supplement. "Physical properties of the atmosphere." Marriotte and Boyle.

ALKALI AND IRRIGATION.

The treatment of alkali soils, which are so prevalent in the West, is one of the serious problems of reclamation by irrigation. The salt-impregnated earth, black or white in character, requires leaching and aërating; also systematic draining. It needs sometimes the application of neutralizing fertilizers. Irrigation by flooding may generally appear to remove this evil, but it will be found that leaching and aëration may not prove permanent curatives. The alkaline salts, washed from the surface, are seldom wholly carried away, and in fact, especially by flooding, are seeped into the soil and carried down, to often reappear again on the surface, especially where indifferent farming and waste of water will leave the same unduly wet or allow the forming of puddles, pools, and standing bodies of shallow drainage or phreatic waters. The most effective, remedy, then, in addition to leaching and aëration, is that of sub and deep drainage, especially the former. The adaptation of plants to alkali soils needs to be closely studied. Wheat can often be profitably sown; forage plants also, especially alfalfa, which has in a great degree the qualities of neutralizing the injurious salts. Root crops, carefully selected, are also excellent aids in the eradication of alkali. The best are beets, rutabagas, mangoes, which take from two to three years to absord the salts, but they do it quite effectually. Sugar beets are more rapid, but the first crop used on alkali soil is of no value. Potatoes and artichokes can both be used on small areas, but they are not so efficient as the several beet roots. Irrigation farmers who expect the water to do all the reclaiming are sure to be disappointed. The application of "land plaster" or sulphate of lime, in combination with stable manure, by which sulphate of ammonia is produced, is of great value in eradicating black alkali. The white alkali earth is less noxious or injurious. In dealing, then, with alkali soils the irrigator must leach or wash them well; plow deep and pulverize thoroughly; then prepare, if the conditions demand, for both sub and deep drainage. With these in hand and proper use of land plaster and special crop planting, he may, nay, nearly always will succeed in reclaiming land, which, irrespective of the alkaline salts in it, is generally very rich and remarkably productive. Such reclamation is seldom or never a problem beyond reasonable solution.

In chemistry the alkalies belong to the class of caustic bases, such as soda, potash, lithia, ammonia. These are the alkalies proper. The alkaline earths are magnesia and lime. Magnesia with oxide and other compounds of iron with oxygen belong also to the class of insoluble bases. The principal compounds or salts of alkali, which are formed by union with acids, are the sulphate and carbonate of soda (glaubers and washing sodas) andchloride of sodium or common salt. In smaller amounts, but not always, are found also, sulphate of potash, phosphate of soda, nitrate of soda, saltpeter, and carbonate of ammonia. These last five are recognized fertilizers. The "black alkali" results from a combination of carbonate of soda with black humus, or vegetable mold, and in this way is formed the most injurious of alkali soil. It can readily be recognized when dry by the dark rings left on the margin of places formerly wet. The white alkali is the result of the combination of the glaubers and common salt; the alkaloids are from the bases named, formed and found in many roots, such as the sage brush and other indigenous plants of the arid region.

The cropping out of alkali on lands under irrigation is due largely to the almost reckless waste of water common to earlier irrigation efforts. The evil effects of waste by undue flooding, by standing surface pools, and by the sideway seepage or soakage from canals made through porous soils, the effect of which has been to raise the phreatic plane or table, thus bringing again to the surface the alkali which was soaked and seeped in on the first floodings that followed the use of irrigation, are now being greatly mitigated in California. E. W. Hilgard, professor of agriculture in the State University of California, and director of the state experimental station, is doubtless the best American authority on the subject of alkali soils and waters. He does not consider the presence of alkali an unmitigable evil, and under some conditions and to certain crops thinks it is even of advantage.

In dealing with this evil it must be borne in mind that when water sinks only vertically, by reason of its hydrostatic pressure, it causes the ground water plane to rise at remote points, and forces moisture to the surface which does not necessarily come directly from an irrigation ditch, but which may have been a component part of the ground water for years past. Water thus permeating, and at times saturating, the soils that are rich in salts, ordinarily classed as alkali, are sure to dissolve more or less of these salts, and it will retain them in solution until sooner or later some portion arrives at the surface and there evaporates. Though the quantity of salts in solution may be very small and imperceptible to the taste, yet the effect on the soil of the continual upward motion of water is ultimately sure to become apparent. At the surface the soluble salts are deposited, and at the surface and in the surface soils there will be a gradual increase of mineral salts. The white efflorescence so frequently making its appearance on alkali soils, at the commencement of a long dry season is directly due to this cause, whether the upward moving water be supplied artificially or otherwise.

It is evident that the alkali of surface soils may be variously affected by rains according to the amount of rainfall and its duration. A light rain which wets the ground only to a depth of a foot or two may dissolve the efflorescence and all alkali crusts on the surface and carry the salts back into the soil. Some of them will return to the surface in the course of time, when the moisture returns and is evaporated at the surface. A long, continued steady rain may send a large amount of water vertically down through the surface soils to ground water. The salts leached out of the surface soil will pass into the ground water, and may perhaps be carried off to some other region. A sudden heavy rain, on the other hand, may dissolve the salts on the surface, and flowing in depressions, creeks, and sloughs carry it into streams that flow to the ocean. Only in the latter case is there any certainty that the alkaline salts carried off have been disposed of permanently.

The simplest remedy for such evils suggested by their cause is to secure a preponderance of the downward motion of the moisture. If this can be done more of the salts leached out of the soils by water will move downward away from the surface than upwards toward it. The quantity of alkali at the surface where it is most injurious will necessarily be decreased. The remedy will be made still more effective if under drainage is resorted to, *i. e.*, if the water descending to the subsoils through the surface soil be in a large part carried off into natural channels.

The downward motion of water can be secured by copious flooding. Ordinary flooding may prove an injury instead of a benefit, because in case of ordinary flooding the soil is wet to such slight depth only, that capillary attraction and the hydroscopic properties of some of the alkaline salts cause a return of all or nearly all of the water that has been put on the surface, and it comes back from the saline subsoils freighted with more alkali than it carried down to them.

By flooding copiously and draining off the water from the surface of the land into natural drainage channels, some of the salts can be permanently disposed of, but too much reliance should not be placed on this method of getting rid of alkali, because the process of flooding affords ample time for the water which wets the surface layers of soil to dissolve the salts and carry them into the ground, where they remain, while only the water which holds the least salt in solution is drained off from the surface.

Flooding and surface drainage is for this reason an imperfect remedy. Deep plowing always mitigates the evil, because the alkalies accumulated at the surface are turned under and, as is well known, the alkali at the surface has the greatest power to do harm to tender stems of young plants. By frequent tillage capillary attraction from the surface downward is interrupted and the amount of moisture reaching the surface to be there evaporated is diminished, consequently the amount of alkali brought to the surface is thereby reduced.

It has been difficult to ascertain with any degree of precision what has been the cost of preparing lands for irrigation and what the annual cost of applying water to the land. As but one method of irrigation has found favor for all the different kinds of crops raised, the variations of cost depend principally on the topography of the surface to be irrigated and the permanency of the irrigation ditches.

Mr. H. Scougall, of Salt Lake City, a civil engineer with considerable experience in British India and the Australian colonies as well as in the United States, in a recent paper suggests that water should be sparingly used in irrigation where there is any danger of the appearance of alkali. This advice should, as a rule, be followed under all circumstances by all irrigationists.

Sub-drains from 18 to 36 inches below the surface are the best means of removing alkaline and surplus waters. Deep open drains are also of importance, but successful irrigation in general farming will be found to require subdrainage. There is another possibility to be considered as to the value of such a system. All waters which have passed over growing crops obtain thereby an increased amount in solution of nitrogenous material. Their return by drains to the chief irrigation supply may very often prove of value as a factor in fertilization; the more so that all drainage carries with it nitric acid and potash, while losing most of the injurious salts the alkali land has held.

To ascertain the presence of carbonate of sodium there are several tests that may be applied by any farmer. Standing water in low alkali spots has a dark brown tint. It will turn turmeric paper dyed yellow to a brown, or blue litmus paper to a red tint. Gypsum water will detect the presence of carbonate of sodium in any suspected water to which it may be added. Gypsum is excellent as an anti-alkali, where carbonates and borates are detected. Lime, well harrowed in, is also of value. In India the "reh" or alkali is disposed of by leaching or washing it out of the soil affected. The water is then drained or drawn off before soakage can ensue. In both India and Egypt such washing is most successfully done during the winter months. The analogy will probably hold good for a large portion of our arid region. The reason for it is that the water is more clear, and being cold is not likely to sink into the soil. Mr. Scougall's paper states that—

> For three or four years a company has been at work near Alexandria, Egypt, reclaiming the land under Lake Aboukir. The lake itself covers an area of about 35,000 acres and the water is being removed by means of centrifugal pumps. A fresh-water canal has been constructed around the lake, whereby the land from which the water has been removed has been washed. Small dams have been used to retain the fresh water on the newly exposed surface for several days, and it has been found that fresh water will take up 3.5 per cent of salt and become the same specific gravity as sea water. Several acres have been reclaimed and are now under cultivation.
>
> As to India, the evil has long been a prevailing one. In 1760 "reh" existed all along the West Jumna Canal, in the northwest provinces. From 1800 to 1830 the canal was abandoned and "reh" disappeared. In 1838 the canal was reopened and trouble was soon experiened. Since 1838 the Indian Government has constructed several miles of deep drains and limited the amount of water used in irrigation. In addition the natives must now, at least in some instances, pump water from the canals instead of drawing it from head gates, as formerly. This, of course, reduces waste.

The effect of such drainage has been to largely reduce the alkali.

But the methods of treatment of alkali employed in California are of value to the intending and operating irrigator. Professor Hilgard has treated of this at length,* and his views are of such value that, eliminating local references, they are condensed here:

> All regions having a deficient rainfall and requiring irrigation for successful agriculture have tracts of land afflicted more or less with "alkali;" that is, showing during the dry season a "blooming-out" of soluble salts on the surface of the ground. This phenomenon is the direct and inevitable result of a scanty rainfall and a naturally productive soil. The mineral matters required for plant nutrition are being set free by the natural processes included under the general term of weathering; that is, a decomposition of the minerals contained in the soil, among the products of which are always the soluble salts of the alkalies (potash). The potash salts are mostly retained, and form an important part of the mineral food of the plant.
>
> Where the rainfall is scanty, and especially where showers wet the soil only to a light depth, current washing-out can not occur. The sodium salts necessarily accumulate in the soil, together with those of potash, lime, and magnesia, which usually are wholly or in great part retained by the soil. Each time, then, that the soil moisture evaporates between showers it carries with it to the surface in solution whatever of soluble alkaline salts may have accumulated within the depth to which

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* Experimental Station Bulletin, California, No. 83, pp. 140-144.

it penetrated, to be again washed down by the shower to such depths as its amount may justify. This process is indefinitely repeated with one and the same quantity of alkali salts, diminished only to the extent to which some heavier shower may wash away part of the surface accumulation. Hence the lower ground will, as a rule, show a larger proportion of alkali. Being naturally richer in the fine and easily decomposable mineral powder carried down and deposited by the streams, this low ground will develop proportionately more alkali than the higher land. We often find such lands, and even the river bottoms, heavily incrusted, when the adjacent uplands are practically free from alkali. The richness of such valley lands is in proof.

Alkali salts vary in composition, but usually consist of three principal ingredients. These are, in the usual order of their abundance, common salt (sodium chloride), Glauber's salt (sodium sulphate), and sal soda (sodium carbonate). The latter, when present in predominant quantity, gives rise to what is known as "black alkali," from the fact that the sodium carbonate forms with the humus of the soil a dark-colored solution, which, on evaporation in mud puddles, leaves black rings on the soil and surface. The distinction between the "black" alkali and the "white," consisting mainly of the relatively innocuous Glauber's and common salt, is important, for the effect of carbonate of soda upon vegetation is many times more injurious, not only because of its direct corroding effects upon the root-crown when it accumulates near the surface, but also because, as already stated, it dissolves that highly important ingredient, humus or vegetable mold, and, moreover, renders clayey soils almost completely untillable. The latter effect is seen in the low-lying alkali spots, where the soil in which the clay accumulates is so obstinately caked together as to render it extremely difficult to put in the plow. The heavy intractable clods are most difficult to break up. This difficulty does not exist in the case of the "white" alkali soils; they till kindly, and the only trouble lies in the accumulation of the salts at the surface, in consequence of evaporation, to such extent as to injure the surface roots and root-crown. Carbonate of soda or "black" alkali is converted into the "white" (*i. e.*, Glauber's salt) by dressings of gypsum or land plaster, and the relief thus afforded is in very many cases all that is needed to insure profitable cultivation. It is only in exceptionally bad cases that enough of any of these soluble salts to injure the deeper roots exists in the depths of the soil or within more than one inch of the surface. This surface accumulation is obvious to the eye during the dry season.

Aside from the three most prevalent ingredients of the alkaline crusts, there are always present a number of others, some of which are of fundamental importance to plant life. Their mere presence in the soluble form proves that the soil contains in a more or less insoluble shape, but still accessible to the plants, all that it can retain of these useful ingredients. Such are particularly the salts of potash and soluble phosphates, both of which are very commonly found in the alkaline salts from the heavier soils; while saltpeter, in the form of both potassium and sodium nitrates, is common, especially in the "black" alkali districts. It represents a surplus of the most expensive of the fertilizers which the farmer finds it necessary to supply to his soils in order to maintain their productiveness.

The most obvious mode of correcting the condition of alkali soils generally is clearly to supplement by artificial means the natural deficiency of drainage through the soil, resulting from the scanty rainfall. For, if we once leach out the surplus salts that have accumulated for ages, it will take ages to bring about the same condition of things and we shall practically have put an end to the "alkali" difficulty.

But this leaching out can not be done by putting water on the surface of the land, unless at the same time its *removal after passing through the soil* is provided for; for it is manifest that if the alkali solution descends farther than the subsoil and remains there, ready to reascend so soon as evaporation at the surface calls for it, we shall have done no good. In fact, the inutility of this mode of procedure has been so thoroughly tested in practice, both in California and in India, as to have shown that it is the reverse of useful and increases instead of diminishing the evil, because the soluble salts thereafter ascend from greater depths than the annual rainfall could have reached and their sum total is thus materially increased. This is the simple explanation of what is known as the "rise of the alkali," which is observed in all lands subjected to surface irrigation for some length of time, creating increasing inconvenience and alarm as time progresses.

Underdrainage is the general and absolute corrective of alkali. To flood the land until underdrains, laid reasonable distances apart, shall have run for some time, will end the trouble, not only for the time being, but for centuries, provided only that solid beds of the alkili salts do not underlie it. But this is the rare exception.

There is, however, in certain regions one difficulty in the way of the success of this operation, namely, the existence of a bed or layer of calcareous hardpan, equally impervious to roots and water. Farmers have already learned that where this hardpan underlies the subsoil at a few feet depth trees and vines will not flourish unless it is broken through, so as to enable the roots to pass beneath.* This "knocking the bottom out" of the holes in which trees are to be planted has already become a well-understood operation in the hardpan neighborhoods, the crowbar, or even a charge of powder, being called into requisition. It is noticeable that in such localities the alkali plague comes soonest and is most persistent, being the natural result of the retention of the alkaline water above the hardpan layer, and its reascent, with all its salts, so soon as evaporation sets in. The obvious remedy in such cases is to make the drainage-ditches deep enough to cut *through* the hardpan and to knock so many holes into the latter as to facilitate drainage to the necessary extent. And where the land is otherwise suitable to special crops, such as fruits, the irrigator will always find underdrainage a paying investment.

In reference to gypsum as a remedy, Prof. Hilgard says:

It is apparent that, so far as the efficacy of the use of gypsum against alkali is concerned, each region will have to determine for itself whether or not its alkali is of the black or white type; and as this can be generally readily ascertained by a simple inspection of puddles on alkali ground—whether or not tinted by the dissolution of the vegetable mold into an inky liquid, leaving black rings on evaporation—no one need be long in doubt on that point. Wherever the black tint appears, dressings of land plaster, ranging from 200 to 500 pounds per acre, will usually effect the change from "black" to "white," after one or two irrigations followed by cultivation; preventing the killing of seeds in the ground as well as the dwindling of seedlings after sprouting, and greatly improving the tillage of the heavier soils. Thereafter, the chief measure toward the prevention of the rise of the salts to the surface is whatever tends to prevent evaporation from the land surface; and therefore particularly the maintenance of deep and thorough tilth and the avoidance of the formation of any surface crusts. These means, together with a proper choice of crops and mode of culture, will serve to maintain good production in most cases until the radical cure by *drainage alongside of irrigation* shall be justified by the increased value of the land.

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* Such a danger may be found in Southwest Idaho in the otherwise rich region of the Boisé and Fayette valleys, where a volvanic hardpan is found.

THE PHYSICAL CONDITIONS

AND

PROGRESS OF IRRIGATION.

CONTENTS.

	Page.
Arizona	
California	57- 80
Colorado	81-126
Idaho	127-159
Montana	160-177
New Mexico	161-197
Nevada	198-227
Oregon	228-237
Utah	238-245
Washington	246-265
Wyoming	266-275
The Great Plains—Kansas, Nebraska, the Dakotas (North and South), Texas	276-287
	288-298

LIST OF MAPS AND ILLUSTRATIONS.

	Page.
Rio Gila Valley, Ariz., unreclaimed lands in	
Mohawk Valley, Ariz., looking southeast	57
Raising water from a lost river, Arizona	65
Phreatic waters in Arizona	72
Orange orchard, Los Angeles, Cal	76
Turlock and Modesto Dam, Stanislaus County, Cal	81
Modern cement ditch, near Redlands, Cal	100
Zanja or old-style ditch, near Redlands, Cal	107
Cement hydrant and flume, near Redlands, Cal	111
Irrigated garden and orchard, Tulare, Cal	119
No. 1 Flume, Colorado Canal, Arkansas Valley, Colorado	122
Diagram, water strata, Colorado	132
View of Greeley, Colo., 1870	135
Garden by irrigation, Greeley, Colo	141
Canals of Otero County, plan of, Colo	145
Plan of Big Sandy underflow, Colorado	147
Diagram representing canal wear, Colorado	150
Artesian basin, map of, San Luis Valley, Colorado	151
Irrigation by seepage, San Luis Valley, Colorado	153
Map of southern Idaho	155
Rocky Cañon Trestle and Flume, Montana (Gallatin Valley)	169
Irrigation by check, Montana (Gallatin Valley)	190
Rio Pecos near Roswell, N. Mex	192
Irrigated market garden in Santa Fe, N. Mex	198
Raton table land reservoirs, New Mexico	206
Irrigated orchard near Roswell, N. Mex	209
Rock cut on curve, Pioneer Canal, Texas	221
Residence and orchard near Eddy, N. Mex	221
Sage brush and alfalfa, Wadsworth, Nev	224
Underflow works, Emigration Cañon, Utah	230
Irrigation map of Wyoming	250
	281

Rio Gila Valley and Unreclaimed Land near Yuma, Arizona.

IRRIGATION IN STATES AND TERRITORIES.

ARIZONA.

The messengers who brought the news of the "land of promise" were ridiculed. Their report was doubted because of its very truth. The ruins that mark some of the valleys of Arizona and the lines of prehistoric canals that still wrinkle their surface tell of the life that has been and promise nature's bounty to future irrigators. Even in its arid expanses the traveler remains entranced. After entering the Territory, mountain walls tower around him at every step, which the constant sunshine paints with vivid tones. As he proceeds into the settled portions, the luxuriance of the tropic growth is encircled by the desert cactus, and gardens of magical beauty dispute the land with the fantastic vegetation of an arid desert. In a little while, however, the irrigator lengthens his ditches, and the gold and green of harvest overspreads the face of nature. For the last quarter of a century the growth of the Territory has proceeded by small but sure degress, the population following the lines of the canals; and each year sees a new, if small, area brought under the dominion of man. In this struggle it is interesting to note how closely the modern cultivator has traversed the canal lines of the elder agriculture. In the Salt River Valley a map will show the present ditches, sometimes in the beds of the old water ways, but never diverging to any wide variance. It is doubtful, indeed, if the Mésa City Canal would have ever been built had not an old rock cut been discovered, by which great labor and expense was saved the early settlers. The reclamation of Arizona is simply the repetition of history. A portion of the country once supported a populous life.

The modern records of precipitation, as analyzed by Lieut. Glassford, of the Weather Bureau of this Department, show that there is sufficient water if properly distributed and applied to support a greater one throughout the Territory. It is of interest to note that while many remains of a once widespread irrigation system are apparent, there are no evidences of high storage or artificial lakes. Certain theorists, however, have determined that the future of Arizona lies in the construction of enormous storage basins to hold the storm and winter water; yet practical experience is demonstrating that the success of a general system of reservoirs in Arizona may be very doubtful. The amount of sedimentary matter carried down the cañons of the Gila, Salt, and tributary streams is enormous. The problem of storage has another difficulty in Arizona, for bed rock seldom comes within many feet of the river or stream surface; and it is doubtful if many reservoirs could be constructed that would not either fill with detritus, silt, and sand, or be able to resist the force that may wash out its dam during a spring flood. The flood of February, 1891, washed away a stage station at Phœnix that had been built since 1858. According to the observation of several local engineers, if that flood had been restrained sufficiently to deaden the force of its water it would have deposited enough matter to bury the city of Phœnix 200 feet deep. The débris traveling in the water wore iron bolts 3 inches wide and $\frac{5}{8}$ inch thick down to a feather edge. Iron nuts were worn off, and 4-inch planking was reduced in size to 1 inch. The problem of storage has been carefully considered by the local irrigators and inquirers, and abandoned for the present as too costly for the resources of the community and dangerous. Dams in the beds of torrential streams are never likely to stand the tests required for security.

Under the present irrigation system two and three crops per year of the staples can be raised. Vegetables, such as celery, tomatoes, and beans, and fruits like melons and strawberries, can be raised during the winter in the open air. The slightest irrigation will suffice for these crops, and in the season water is abundant in all the streams, and is supplemented by rainfall in the valleys. The orange, the grape, and the fig need the heat of the ever-bright summer, but every month in the year has its crop. The Chinese raise enormous quantities of vegetables during the winter on very small areas, the only limit of production being the market, which, on account of incomplete railroad facilities, is practically confined to the farmers' immediate neighborhood.

Under the direction of Congress the United States Signal Service has prepared a series of able monographs upon "Irrigation and Water Storage in the Arid Region." The experience of the writers therein in connection with the Weather Service gives to their views and conclusions the weight of expert authority. In this place it will only be necessary, as part of the review of progress that belongs to the irrigation inquiry, to briefly refer to some of the chief conclusions they have reached. Lieut. Glassford, whose knowledge of our southwestern region and its climatology, is most extensive and accurate, says in his report on Arizona:

> In general it may be said that the question of the reclamation of any arid land presents itself for discussion under five topics, which it is well to note. They are: (1) Geography and hyetophysics of the region; (2) amount of land which may be irrigated; (3) amount of water which may be used for irrigation; (4) economy of irrigation; (5) legal questions involved. The lines of division between these topics can not be sharply drawn; each involves consideration from several points of view and thus comes within the province of several studies.
>
> The economical and legal questions are to be settled by the intending investor and his advisors; the amount of land and the amount of water available for use upon it are to be determined by engineers; the meteorological student may in pursuit of his researches find himself involved in the discussion of any or all of these topics, but his special province is the hyetophysics as affected by the determining facts of nature.

As a matter of course the chief importance of the papers under consideration consists in their precise and able review of the climatological conditions affecting and controlling aridity. It is therefore of importance to present as briefly as possible the salient factors in such reviews. Lieut. Glassford discusses Arizona, New Mexico, and California. Practically also, the State last named indicates the chief elements of the problem of aridity in connection with Western Nevada, and the eastern portions of Oregon and Washington.

To begin with Arizona then, Lieut. Glassford says, with the special agent in charge of the irrigation inquiry and all other authority on the subject, that the study of hyetophysics, or of the original search for the causes of climatic laws and effects, must be the first one made. The farmer, the investor, the engineers appreciate the existence of the rich alluvial bottom land, and of the fertile areas embraced by the table or mesa portions of the topography. The reclaimability of these areas is within their province, but in order to work most intelligently they must be in possession of the data. Mr. Glassford states with force that—

> The origin of every grain of humus in the lower rivers is to be found on the jagged mountain peaks, on the bare plateaus, and in the eroded cañons of the central and northern portions of the Territory; the origin of every drop of water that flows to waste upon the shoals of the Gulf of California, of every inch of water that by wise forethought has been applied to the moistening of a soil, so rich as to need no reinforcement of artificial fertilizers, must be sought in the winter and summer rains, in the lingering mountain cap of snow, and in the destructive suddenness of the so-called cloudburst.
>
> These are the elements of the problem, which must be presented briefly and succinctly in order that it shall be clearly appreciated from the outset, that:
>
> (1) The causes which have produced the alluvial bottom lands are of continual and present operation, and are to be counted on to restore all waste, whether it be the molecular loss of soil washed away as detritus or the chemical waste of soil depauperated by the growth of crops.
>
> (2) That these causes must be accepted as constant factors, not to be altered or avoided, but whose actions may be diverted to channels which shall aid rather than retard the enterprise of human industry.

It is unnecessary to present the review of physical geography which follows, further than to say that Arizona "presents the problem of rain catchment, water storage, and economical distribution, together with notable reclaimability of the land to be irrigated, in terms of almost ideal simplicity."

The trend or axis of the mountain system is well defined and distinct. It runs mainly from northwest to southeast. In the subsidiary range the same axial trend is apparent, and the whole formation indicates the controlling forces which affect the aqueous conditions of the atmosphere, pointing directly to the Southern Pacific Ocean, its currents and winds. Mr. Glassford says:

> In passing it is well to note an important result of this uniformity of the mountain axis carried out constantly over more than 500 miles, and one which will receive more extended consideration in its proper connection, and that is that the prevalent moisture-bearing wind is from the southwest, at right angles to the broad side of the mountains, and thus encounters the maximum bluff surface. In other words, the passage of the rainy winds across Arizona is by no means an easy gliding over an inclined plane, but the laborious ascent of a flight of steps.

He makes use of a striking comparison by presenting the main formation as "the continental V." This begins in Arizona at an altitude of 3,000 feet, and is not one merely "of contours and rock masses."

The line of 3,000 feet "marks with equal distinctness an important difference in the soil, an astonishing difference in climatic features, and so great a difference in commercial and economical value that it at once suggests the idea that nature has here balanced means with end. The partition is unequal southwest of the dividing line, roughly speaking. One-third of the Territory lies below the level of 3,000 feet. Northeast of the same line two-thirds of the Territory is a lofty plateau. The plan has the fertile soil and the minimum of rain. The plateau receives abundant rain upon its rocky surface and retains almost none of it. The plain is the garden. The plateau is the reservoir of water and the storehouse of life for the soil."

In the area thus indicated, "save a small number of exceptional instances, whose acreage is inconsiderable in comparison, the plain thus defined contains the lands economically available for reclamation."

More than half the Territory "is measured above the 5,000-foot contour," and forms in general what is known to geographers as the Colorado Plateau. To the eastern extremity thereof, and within New Mexico—that is, the plateau or table land of the Raton Mountains—there is in progress a remarkable development of irrigation, the success of which, already quite well determined, may indicate the possibility, even probability, of extending the area of irrigable reclaimability over a vast region heretofore wholly given up to sparse cattle grazing and sheep husbandry. At any rate there is reason to hope for an association of arable and pastoral industries through both open water storage and phreatic supply, by which small areas cultivated for grain, roots, and forage may sustain larger ones brought under fence and use for stock breeding and raising purposes; so that cattle farms rather than ranches will be the order of the near future.

The river systems of Arizona are two. North of its great divide is the Colorado, approximately controlling one-half of the Territory. It has but a small number of affluents, which however are sufficient to carry off the scanty rainfall. South of the great divide is found the more important watershed (from an irrigation point) of the Gila and its tributaries. Of the plateau divide it is said: " North of it the rivers flow for the most part in deeply-eroded cañons. South of it are level valleys and basins which it is clear have in recent geologic time contained immense inland seas of the order of Lake Bonneville, or the similar region immediately to the north."

One difficulty in the study of " precipitation phenomena " in Arizona, as well as elsewhere in our mountain region, arises from the fact that the stations for meteorological observations are for the most part in valleys and cañons. The heavy rains occur on the high altitudes. While in the lower Gila and Salt River valleys the annual precipitation seldom exceeds 7 or 8 inches, and is often much less, it is a matter of constant observation by the traveler that the proplateaus, the table land, the mountain slopes, and the overtowering summits and peaks may be black with storm and every arroyo or channel be filled with a torrential flow. " Nor," says Mr. Glassford, " is this confined to the mere sight of showers which go unmeasured. During the winter the most casual observer of the streams sees periods of high water amounting at times to turbulent flood, which are so little to be accounted for by the record that the conclusion is irresistible that existing records indicate only a fraction of the actual precipitation which can be relied upon for water storage, and that these data represent perhaps the minimum quantity of the rainfall. Yet, despite this known disproportion of the recorded and actual efficient rainfall, it has," says Mr. Glassford, " been shown that the measured amounts are sufficient to supply water for the irrigation of much more land than the acreage known to be available."

This last statement is of value as contrasting with another made in a bulletin of the United States Census to the effect that with 65,821 acres (the area given as cultivated by irrigation in the fiscal year 1889-'90) there is no more available water "in sight" for the extension of the area of cultivation. The amount of land " under ditch" at the same period is given as follows:

	Acres.
By the Governor of Arizona	587,460
By Mr. F. H. Newell, U. S. Geological Survey	455,000
By United States Senate Irrigation Committee report	529,200
Or an average of	523,887

Mr. Glassford's statement, it will be observed, is that the " measured amounts " of water—and therefore " in sight"—" are sufficient to supply water for the irrigation of much more land than the average known to be available." It must be borne in mind that Mr. Glassford's " measured amounts" of available rainfall does not embrace the "storm waters," the storage of which is the objective point of the agent's limitative remarks in the census bulletin referred to. Mention is made of this difference of view because the same factors exist over all of the arid region in greater or less degree, as Mr. Glassford points out in the paper on Arizona to which reference is now called. The necessity of providing for distinct, definite, and continued weather observations in high altitudes is emphasized by the conclusions presented by the weather service experts. No greater service can now be rendered the practical consideration of reclamation by irrigation than the establishment of mountain observatories and the inauguration of climatological investigation, having specially in view the cosmical laws affecting our Cordilleran water supply.

The division of Arizona into "plain, proplateau, and plateau" serves also to mark the division into two essentially "variant systems of isohyetal curves." The curves of the physical system are the lines also of precipitation and its changes. Both reproduce "the characterizing axial inflection of the mountain mass." The plain has no great elevation or high ranges. Hence its rainfall is not within, to any large degree, the corrective effects required by the unmeasured fall upon higher altitudes, in other portions of the territory. Speaking of the Colorado Basin region around Fort Mojave, Mr. Glassford says:

> Upon this low plain the rain records approximate the absolute minimum of the world. It is from the reports of early travelers in this region, as rainless as the Saharas or the central plains of Australia, that has sprung the common belief that Arizona was agriculturally worthless because of its aridity. Hunters and trappers in search of game, emigrants wearily accepting the desert as the hard path leading to the promised fatness of California, prospectors seeking placers and pockets, had neither time nor inclination to think of aught but the means of protection against the Indians. They found their road lying over sandy plains, where springs were far away and where the sky was seldom clouded with rain. Carelessly they called the land a desert, carelessly their hasty decision spread, and now this prejudice, founded on ignorance and faulty observation, yields but slowly to the argument of facts.

The pro-plateau and plateau sections are associated together in Mr. Glassford's review. The "extensive" high lands thereof exercise the largest influence as "rain-makers." With one exception, too, "the isohyetal curves tend to follow the axial inflection" of the mass. "With sufficiently remarkable regularity the curves of annual rainfall, amounting to more than 10 inches, fall quite to the south of the great divide, and thus indicate for the Gila watershed a considerable superiority of water supply over the Colorado system."

These curves "also draw in water" the division between plain and plateau. The curve of 15 inches is to the southeast and embraces the region drained by the Santa Cruz and San Pedro rivers. The 20-inch curve is also located in southern and central Arizona. The highest curve shows a fall of 25 inches, and "accords with the roots of the San Francisco Mountain" in the northwest.

The seasonal relations of the rainfall are of marked importance. Mr. Glassford says:

> Arizona has two plainly marked rainy seasons, a fact which largely balances the relatively small precipitation. In this, as in every particular of the study of precipitation in the Territory, it should be noted that the physical features are such as to lead all rain precipitation down the steep mountain side, everywhere approximating perpendicularity with such rapidity that the surface which receives the rain is little benefited thereby, and the valleys are almost instantly affected.
>
> The season of winter rains begins in December with a marked absence of precision in definition, but at the other end in February its termination may be predicted within narrow limits. The precipitation during this season is neither so great nor so much to be relied upon as the rains of summer, yet it serves a regulating purpose,

whose direct influence upon the climate and the more particularly hydraulic features now under discussion is persistent for months after the definite conclusion of the season which produced it. The precipitation at this season is both heavy and general while it lasts. The season presents a series of weather types which have been the subject of some study in connection with their annual and secular appearance upon the Pacific coast. In brief, the storms are of the sort conventionally known as cyclonic or low barometric areas, between which are interpolated anticyclonic areas marked by extreme cloudlessness and slight humidity. As in the case of the seasonal rains of California, so in Arizona, the variability of the winter rains in amount and frequency is in the ratio of the intensity and recurrence of barometric disturbances. To this characteristic feature is due the intermittent effect of the rainfall, which gives the streams both high and low water during the rainy season. To such an extent is this tendency carried that in time of drought some of the streams become mere rills, and even disappear altogether, either because of total failure of the source of supply or because the water has sought underground channels beneath the great deposits of detritus, sand, and silt which have washed into the beds of the streams on account of the rapidity of passage of rain water to a distinctly lower level over mountain sides of notably steep pitch.

Despite the fact that the amount of rain precipitated during the three winter months is measurably less than in summer, it never fails to flood the streams. The reason for this has already been indicated in the sharpness of the contours of altitude. The low temperature which prevails upon the plateau during this season also tends to magnify this result. The soil of the mountains, naturally little pervious, is made still more impermeable by the freezing of rains upon it, so that succeeding rains fall upon glare ice and are hurried to the valleys with a minimum of absorption by the soil. Much of the precipitation of the winter rainy season occurs in the form of snow, which is retained upon the spot where it falls. Succeeding falls add to this mantle of stored water until it is by no means unusual to find it on the mountains all the way from 3 to 7 feet deep. It thus appears that the total winter precipitation is naturally resolved into two components, of which one, the rain precipitation, has an immediate though evanescent effect upon the streams, while the other, the snow precipitation, exerts an influence more permanent in proportion as it is less immediate. This mantle of snow is in fact a great storage reservoir with neither dam nor dike, and automatic in its regulation of supply to the causes which avail in producing demand. It remains upon the plateaus of high altitude upon which it has fallen for months after the definite conclusion of the rainy season, and is frequently observed to persist until nearly the beginning of July. Its gradual melting serves to keep a quantum of water in all the streams throughout the dry season almost to the beginning of the summer rains.

The summer rains come in July, August, and September, being somewhat sharply defined from the preceding dry season, but shading so indeterminately toward the beginning of the winter rains that it becomes quite proper to say that, while Arizona has two rainy seasons, it has but one dry season. Although there is no positive delimitation of time between the rains of summer and those of winter, there is to be noted a differentiation of character. The rains of winter are caused by the proximity of approach of great storms in low-pressure areas which form a part of the storm system of the country at large. The rains of summer are local in character and directly traceable to mountain influences, with a distinguishing peculiarity which should be noted for future study. In general the amount of rainfall is greatest in districts toward the point from which the prevailing wind blows; in Arizona the greatest pluvial effort is registered on the leeward side of ranges. A noteworthy feature of the climatology of the Territory is, that when the last snow disappears upon the mountain summits the summer rains commence. So constant and so well appreciated is this relation that the oldest settlers, and the Indians before them have been in the habit of calculating the coming of the rains in accordance therewith.

It has been noted that the summer rains are of local character; they appear somewhat upon the plain, but their maximum amount and intensity is displayed upon the plateau. While their total amount is considerably in excess of the sum of the winter rains, the amount of any individual precipitation is uniformly less than any one precipitation of winter, and the excess is made to appear through the sum of a long series of precipitations, which are of almost daily occurrence upon the mountain summits. They rarely have any great extent, but their intensity is so remarkable a feature as to warrant particular consideration.

The fact that showers are observed almost every afternoon upon the mountain summits, and most uniformly only in the afternoon, points directly to this cause, which may be briefly discussed. A well-established law of atmospheric temperature is that it decreases with the elevation, a law whose operation is easily seen upon snow-clad mountains, where the snow line gradually rises with the increasing heat of summer. During the persistence of the snow the actual decrease in temperature on the moun-

> tain sides is nearly equal to the theoretical decrease with elevation. The white snow surface by its reflection of incident solar heat tends to keep the mountain mass at a low temperature, and possibly such a surface absorbs no more heat than air of the same elevation; at best its coefficient of absorption is small. Thence it results that above the line of actually persistent snow the vertical isotherms may be conceived to differ but slightly over the plateau and over the extensive summits. With the final obliteration of the snow a marked change occurs. The rock surface now exposed absorbs heat and speedily converts the mountains into a radiant body of conical form. The strata of air cut by this cone of radiation and strata lying above it become at once disturbed, convection is instituted, and as the influence spreads over a considerable area, great amounts of air are in a short time lifted to a great height, and in the resulting operations of expansion, cooling and condensation, the upper currents distribute the rain over the plateau and particularly to leeward. By parity of demonstration, the same principles may be shown to account for the diurnal periodicity of these summer rains.
>
> From the foregoing considerations it appears that the rainfall of Arizona, computed on the basis of the present records, whose inaccuracy is known to be subtractive, *is more than sufficient to irrigate the reclaimable soil, great as its extent is known to be.* The miximum rainfall of any of the years for which records have been kept is not so great as to burden the usual engineering appliances for handling it, and the possibility of cloud-bursts simply necessitates the construction of stronger retaining works and the maintenance of emergency wasteweirs. The great question to be considered by the engineer in connection with each stream is its hydraulic potential, the maximum amount of water available at the close of the period of minimum supply. That this is sufficient for all his uses is clear from the observations of the meteorologists, of which a summary sketch has here been presented.

Two other factors of importance are treated. These are "evaporation" and the "mechanical equivalent of wind power." The Monthly Weather Review for September, 1888 (p. 235), is referred to as "the first definite step" towards studying evaporation as "an essential climatographic datum." Mr. Glassford states (Irrigation and Water Storage in Arid Region, p. 307) that—

> In general it may be said that the amount of evaporation depends on the dryness of the air, the velocity of the wind, the temperature of the evaporating water, the extent of the evaporating surface, and, other things being equal, varies inversely as the barometric pressure. It is possible also that the amount of evaporation may be reduced by the height of the banks of the reservoir, or, what amounts to the same thing, the lowering of the water level.
>
> Instrumental records were carefully taken at a number of stations in this country between July, 1887, and July, 1888. Four of these stations were in Arizona, and the records of these posts are here presented as they appear in the Monthly Review. They serve to indicate what must be the evaporation from storage reservoirs, since, even though they do not give the actual evaporation from every square inch of water surface (and this is uncertain, it is neither asserted nor denied), yet they supply a proportional scale for the comparison of reservoirs within the same or different atmidometric curves:

Station.	1888.						1887.						Year.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
Fort Apache	2.6	3.0	3.6	6.8	9.4	9.1	7.1	6.7	5.3	5.2	4.1	2.6	65.5
Fort Grant	5.2	4.8	6.4	9.2	10.2	13.8	12.4	10.5	9.0	7.9	7.2	4.6	101.2
Prescott...........	1.4	2.8	3.6	5.4	6.2	8.1	6.6	6.5	4.7	4.9	3.6	2.2	56.0
Yuma..............	4.4	5.2	6.6	9.6	9.6	12.6	11.0	10.2	8.2	8.2	5.5	4.6	95.7

> Arizona is, therefore, entirely above the line of 50 per cent; one-half is above that of 90 per cent, and one area therein reaches above the maximum of evaporation in the United States, which is 100 inches.
>
> The greatest amount of evaporation occurs in the plain, which is the region where irrigation is destined to be applied, and the curves of high evaporation include nearly all the projected reservoirs. Yet, on the other hand, it should be noted that the enormous amount of evaporation within the 100-inch curve will scarcely affect the economic features, because in the San Simon and Sulphur Springs valleys, over which this curve is drawn with close restrictions, present indications point to irrigation by utilizing the subterranean flow of waters which are below the reach of evaporating influences. (P. 307.)

In relation to wind power, Mr. Glassford has the following paragraph:

> Enormous power goes to waste all over the land in the wind which blows and is not utilized. The question is one which has engaged the attention of mechanicians, who recognize the power latent and find their difficulty, not in rendering it immediately efficient, but in conserving its energy. For irrigating purposes in Arizona this difficulty needs no consideration; it is sufficient to raise water into a tank or reservoir whence it may be drawn as needed. The wind may not be constant, but its direction is immaterial, and the force which will operate a modern wind motor is very small. Such application of power is very clearly indicated for the fertile valleys of the southeastern corner of the Territory, where abundant streams underlie the soil and may be reached by wells not more than 20 feet deep.

The conclusions reached, then, as to the subjects under consideration, are:

(1) Twice each year there occurs sufficient aqueous precipitation in Arizona to reclaim every acre of land worthy of such reclamation.

(2) The coefficient of evaporation, though absolutely high, is relatively so small in comparison with the total fluid contents of the actual and projected storage basins that it may be economically disregarded as a vanishing quantity.

(3) A measureless amount of *foot-pounds* of available power is daily going to waste in the winds which blow over the land. This power, rendered efficient by wind motors, will suffice to utilize the large subterranean rivers which are known to underlie large areas of rich land.

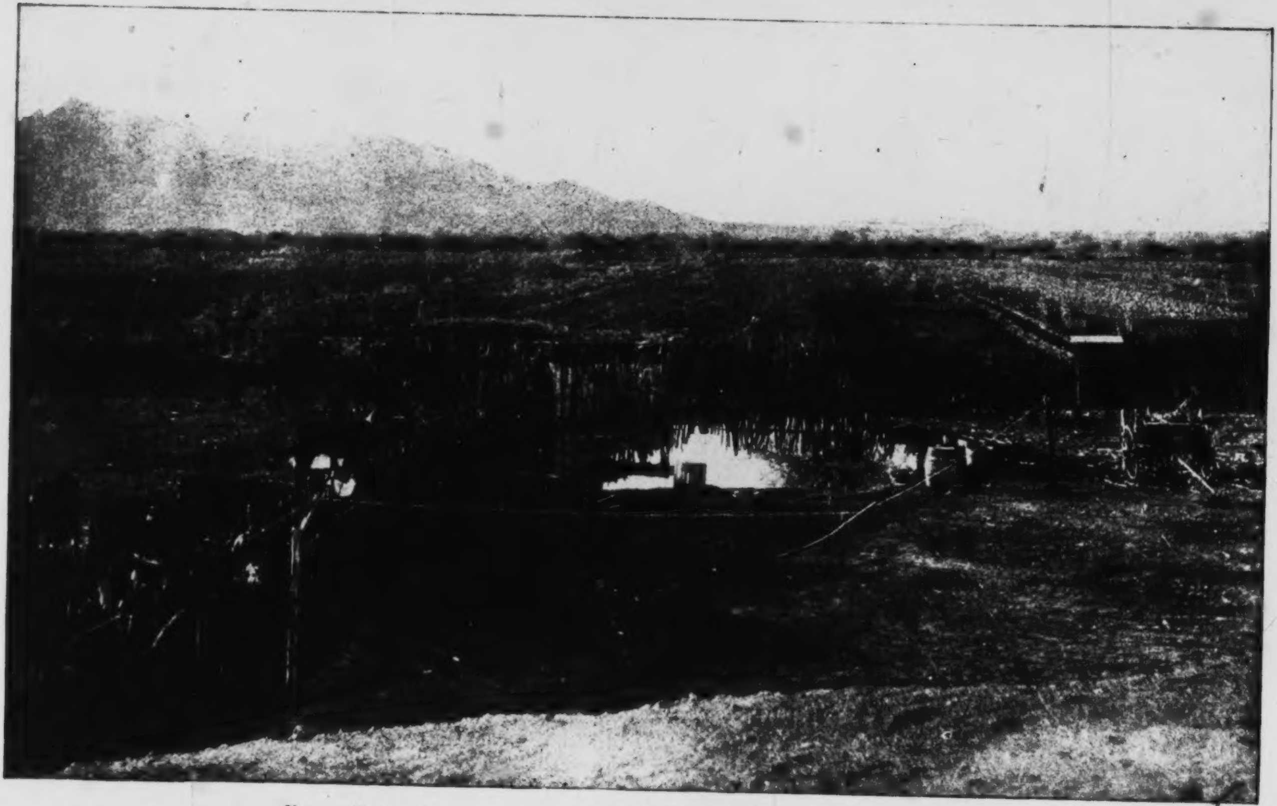
THE SALT RIVER VALLEY.

At present this is the principal irrigated area of Arizona, and obtains its water supply from the Salt River, which heads in New Mexico, 350 to 400 miles to the northeast of Phœnix. The Verde River and a great number of creeks are tributaries to this stream. The Verde heads in the San Francisco Mountains. The entire drainage area is snow-fed. The Salt River Valley main canals are about 300 miles in length, vary from 15 feet on bottom to 36, and are from 3 to 7½ feet deep. There are nearly 5,000 miles of laterals. There are no reservoirs in the valley and but one dam, that at the head of the Arizona Canal, which is 945 feet long and raises the water 8 feet. The area under ditch is 300,000, of which 145,000 are cultivated, at a first cost for water of $10 and an annual water rental of $1 per acre. To clear the land will cost $2 per acre, and to put in grass or alfalfa $5 an acre additional. The irrigation constructions cost from $5.50 to $6 per acre, which cost to the user of water is included in his royalty. The probable average cost to the owners of ditches for annual maintenance and repairs is 60 to 70 cents per acre. Wheat, barley, alfalfa, sorghum, sugar cane, peaches, apricots, prunes, pears, figs, grapes, nectarines, oranges, and lemons, and all staple vegetables are grown all the year through. The average yield is given at the following figures:

		Per acre.			Per acre.
Wheat	pounds.	1,700 to 1,900	Alfalfa	tons.	8
Barley	do...	2,200 to 2,500	Sorghum	do..	30

The raisin area yielded in 1891 7 to 10 tons of grapes per acre from vines three years old from the cutting.

In other parts of the Territory there are important works constructed, and others are contemplated or under way. The Florence Canal covers 60,000 to 75,000 acres. A canal is now being located from a reservoir at the mouth of Camp Creek, where it enters the Verde, 50 miles northwest of Phœnix, and additional storage for the same canal is contemplated at Deadman Cañon, on same river. It will skirt the McDowell



Mohawk Valley, looking Southeast. Part of Rio Gila Valley near Yuma, Arizona.
One year old irrigated ranch.

Mountains, covering a valley of 200,000 acres, bounded on the east by the McDowell Mountains, north by the foothills lying to the northeast of Cave Creek, and on the south by the foothills lying about 8 miles north of Salt River and to the west of Cave Creek.

A storage reservoir is proposed to distribute the waters of Cave Creek, and a similar project is reported in process of construction on the Agua Fria. Here a dam 1,100 feet long is building across the cañon, from which water will be directed in a southeasterly direction, crossing the Southern Pacific Railroad at Gila Bend, for the irrigation of 300,000 acres. The Walnut dam on the Hassayampa is to be rebuilt.

There are several canals proposed along the Gila, which will cover a great deal of land between Agua Fria dam and the junction with the Colorado. The activity about Yuma is remarkable, and that section promises to grow in prominence for its semitropical productions. One interesting enterprise, which is preparing to irrigate by means of water pumped from the Colorado, will be watched with interest.

During the personal investigation of irrigation in the Salt River Valley, in June, 1891, the special agent was waited upon by a committee of the principal citizens and irrigators, among whom were Hon. N. O. Murphy, acting governor; T. E. Ferrish, ex-commissioner of irrigation; Hon. Chas. D. Poston, ex-Delegate to Congress; Mr. Lincoln Fowler, C. E. W. A. McGuinnis, Mr. Wormser, H. H. Logan, of the Phœnix Chamber of Commerce, and others, who desired to present facts concerning the state of irrigation in the Salt River Valley. They complained vehemently of statements officially made to the effect that only 65,821 acres were under irrigation in the Territory, and 35,212 acres in Maricopa County. The answers to the special agent's questions were taken down by Mr. M. A. Downing, his assistant, and are here given. It is only necessary to say further that the answers were all fully canvassed by the gentlemen present, and in most cases are the results of full discussion.

How many irrigation canals are there in the Salt River Valley?

Mr. FOWLER. In the Salt River Valley there are on the north side of the river the Arizona Canal, the Consolidated, which includes the Grand, and Maricopa, Salt River Valley, and Cross Cut canals, and the Dutch Ditch. All are under one management and form an interlocking system. Farther down the river, on the north side, are the Griffin, Farmers', and St. John's canals under independent management. On the south side of the river the canals are the Highland, the Mesa City Canal, the Utah Ditch, the Tempe Canal, the San Francisco, the Marmonier or French, and the Broadway ditches. The canals on the south side of the river are owned in common by the proprietors of the lands irrigated, but the Mesa City Canal is the only one incorporated by the irrigators. These ditches have numerous extensions and branches, and irrigate wide areas.

What is the acreage under these south-side ditches?

Mr. WURMSER. That can not be given just now, but under the Highland there were eight sections or 5,120 acres cultivated during 1890; the Mesa City Ditch cultivates 8,000 acres. The farms under this ditch are all small. It is owned by the Mormons, and they call 10 acres a farm. The Highland Ditch was taken out to cover land taken up under the desert-land act, and the farms are all large. There are none less than 160 acres. The Utah Ditch irrigates a little over 3,000 acres. These farms are also small, about 10 acres. The Tempe Canal waters

10,000 acres; its full capacity is 12,000 acres. The average size of farm under this ditch is from 160 acres to a section, except that there are some newcomers who raise fruit on plats of about 20 acres each, which might amount to two or three sections. I should say, taking this into account, there are 12,000 acres under cultivation. The San Francisco has 10,000 acres of land under it and carries 5,600 inches of water; there were in 1890 about 4,000 acres cultivated. The French or Marmonier Ditch cultivates 4 sections of desert land, 2,560 acres; and besides this there are 400 acres divided into other small farms. This will make 33,120 acres irrigated and cultivated on the south side of the river during 1890, under the farmer-owned canals.

Mr. **FOWLER.** Under the Arizona Canal, on the north side, there were, according to the figures of three years ago, 43,000 acres under cultivation; this has increased to a great extent, and in 1890 there was more than that amount cultivated under that canal. There are between 39,000 and 40,000 acres cultivated under other of the canals belonging to the consolidated system, which figures, added to those already given, will make a total of about 116,120 acres cultivated by irrigation in the Salt River Valley, exclusive of the land under the Farmers' and St. John's canals in the lower part of this valley. The estimate of cultivation in the Salt River Valley made by the Phœnix Chamber of Commerce is 125,000 acres. This takes into consideration the increased cultivation under the Arizona Canal systems, and is very accurate up to date.

Mr. **LOGAN.** We complain of official statements that the maximum amount of land that can be irrigated by the present method of supply has been reached, and that without high altitude storage of water no further advance can be made. There is no storage of water at the present time in the Salt River Valley. Any man who makes the first statement has certainly not seen the country. There is a project for storage, the possibilities of which are very great. But the water in sight will irrigate in the Salt River Valley 300,000 acres. There were in Maricopa County 309,000 acres under canal on the 30th of June, 1890; of that amount there was actually cultivated 45,000 acres in barley, 45,000 in alfalfa, 15,000 in wheat, 5,000 in fruit trees and vines, and 15,000 acres in miscellaneous crops, vegetables, and sugar corn, that make 122,000 acres. There is a large acreage in excess of that not mentioned, most of it being in pasture.

Is it made available by the application of water?

Mr. **LOGAN.** Yes, sir; I think the pastural area would amount to 30,000 acres. There are a great many fields that are irrigated only once or twice, making too small a crop to cut, but still leaving good pasturage. I know my estimate is conservative. I have gone over it several times with great care, and think I am absolutely under the actual figures. Officials should exercise the greatest care in making statements such as are contained in the bulletin to which I refer. They often do great harm to the communities affected.

Then you say there is 135,000 acres of land under cultivation and use by irrigation and that amount was cultivated on the 30th of June, 1890?

Mr. **LOGAN.** Yes, sir; but only 125,000 acres was in a state of fair cultivation. Some of our barley, for instance, is in "volunteer;" that is, not seeded, in but coming up from last year's crop. It receives only one watering generally, possibly two, and produces only about one-third of a crop, which cuts down materially our average of production. There are more acres under cultivation in the Salt River Valley than are reported in Bulletin 35. Any man can be convinced, without the necessity of an enumeration, that there are more than 65,821 acres irrigated in Arizona, and I can introduce you, if necessary, to more than 327 irrigators in Maricopa County.

The statements that you are controverting assets that the county of Maricopa had at date of enumeration 327 irrigators, a total irrigated of area 35,212 acres, and that the average size of the farms is 108 acres, with an average value of products of $9.26 per acre. Will Mr. Logan please tell me whether these figures are correct?

Mr. **Logan**. Well, there are cultivated to barley 45,000 acres, which, according to the best statistics obtainable from the thrashers, yielded an average of 1,000 pounds to the acre and 48 pounds to the bushel. That is the average of the whole acreage. I have not the slightest doubt 10,000 acres of barley ran 2,500 pounds to the acre, probably 10,000 acres more gave 1,500 to 1,600 pounds, and the balance went light for the reasons I have given. The average was, however, 1,000 pounds to the acre. Alfalfa produces here under fair cultivation and good irrigation 8 tons to the acre. The average would be 4 tons to the acre, at a minimum value per ton of $4. I believe $3.50 per ton is the lowest it ever reached. In 1890 the average was $4.50. There were in 1890, June 30, 45,000 acres in alfalfa. Of wheat there were 15,000 acres at the same time. I do not know what is the yield of wheat. Do you Mr. Fowler?

Mr. **Fowler**. About 120 pounds to the acre.

Mr. **Logan**. There has been less poor farming in wheat than in barley. Wheat is worth about $1.25 per cwt. or 75 cents a bushel. We had fruit for exportation or sale in limited quantities. Probably not over 900 acres of the 5,000 acres planted in fruit in this valley is bearing. I will estimate the value of the first crop at $100 per acre, and think that will be quite conservative.

Mr. **Wurmser**. It pays more than that. A man here sold and shipped from 4 acres of peaches enough to net $550 clear of all expenses. Arizona is credited by the census viticultural bulletin with having in the whole Territory 1,000 acres of bearing vines, producing 3 tons of grapes per acre, at $16.50 per ton.

Mr. **Logan**. There never were any grapes sold in this country for less than 1 cent per pound. I was offered only yesterday 1½ cents per pound and that is the lowest ever offered. That would make $30 per ton. Three tons per acre is a fair average. I will say, however, that the major part of the vineyards are not in a good state of cultivation. I see that Arizona is put at the head or as high as as any other State or Territory in the amount of grape product per acre, and that is correct. With vines in approximately good bearing, however, I think 4 tons would be the average, but taking it as a whole I think the figures are about right on that point. Grape cultivation in this Territory is mainly confined to Maricopa County; that is, we have nine-tenths of the area. The value of the plant and land, I notice, is put down at $75,000, but the 5,000 acres of fruit in the valley to-day are worth an average of $100 per acre and upward.

Mr. **Fowler**. One vineyard sold for $200 an acre. There were about a hundred acres; 80 acres in fruit and 20 acres in alfalfa. Two leading ranches have 200 acres each, 100 acres on both being in figs. The returns for 1890 give the value of the crops as $9.26 per acre in Maricopa County.

Mr. **Logan**. I should think that was below the real figures. A good farmer will get for his barley about $25 per acre, and his alfalfa about

$35 and $40; taking good and bad, one with another, I should think $16 would be very low. In wheat I should say $15. Vegetables are almost all raised by Chinamen, and they do not tell what they get, but I know it goes into high figures; I should think from $600 to $700 per acre. So, taking all kinds of cultivation into consideration, $35 per acre would be a low estimate for the product of irrigated land here.

All of these present, with the exception of Mr. Poston, were, at the date of testifying, practical irrigators, who raised crops. They all said that no one ever took the figures of their farms. Besides, many of them own or are connected with irrigation ditches. They all stated that no request was ever received by them for the figures or statistics thereof.

A further statement is that "the acreage under cultivation may be regarded as approaching the maximum possible with the present supply and methods of use." So far as Maricopa County is concerned, is that correct?

Mr. **Logan.** I do not think it has a shadow of truth. The man who made it never investigated, because we have not one but several canals here capable of irrigating all the land he mentions as now irrigated. I can speak with absolute certainty on that. It is only an opinion and the opinion is wrong. He also gives the limit of cultivation in Arizona at 65,000 acres. The area capable of being irrigated from existing supply works will exceed 2,000,000 acres. In the Salt and Gila valleys I believe there is upward of 1,000,000 acres of land that will come under cultivation from the water in sight.

Mr. **McGuinniss.** I think it will be a great deal more than that.

Mr. **Fowler.** I believe the acreage will go away beyond 2,000,000 acres.

You would all agree, then, that 1,000,000 acres would be a moderate estimate of the amount of land that could be reclaimed by the water in sight at this time?

Mr. **Fowler.** People who build canals for profit, and have money to invest, have constructed ditches in this valley alone for 300,000 acres, and a further area in the rest of the Territory. These canals are based on the idea of profit.

Mr. **Logan.** The canal system of Maricopa County has cost upward of $2,000,000, probably $2,500,000. From the ditches now constructed we have a supply for 300,000 acres of land, and with further economy it can be made to serve much more. As the land comes under cultivation from year to year a smaller amount of water suffices, and the surplus not needed for the old land leaves water for the new, so that it is apparent how we expect to irrigate more than 300,000 with the present construction and supply. In 1889 we irrigated as late as the last of September; in 1890, in March and the last of August. Fifty inches of water will irrigate 80 acres of land, that is 50 inches for 45 days. Now the supply of the river furnishes the greatest abundance during the months of April and June, and by May the irrigation of any moment is complete. Then the alfalfa needs little or no water during the irrigating season, as the best authorities here agree that abundant winter irrigation is the best method. There are a number of alfalfa fields. Now, I believe that the land north of Phœnix will simply be watered once, and that during winter, allowing seepage to do the rest. Ten years ago the land would have been entirely barren in 60 days without irrigation, and I believe now with one winter irrigation it would produce as many pounds of valuable food as other tracts at present do with summer irrigation.

Did you have any difficulty in June, 1890, as to distribution of your water supply?

Mr. LOGAN. Our water supply during 1890 was in the hands of a water commissioner, and I think there was no loss of crops. There could have been no dispute during 1890 over this matter in this county, which embraces the great majority of the land under corporation irrigation, because the companies had to obey the irrigation commissioner, who divided the water. The cost of water is put at $5.75 per acre, and I should think that that was a fair statement.

What steps are being taken to increase the water supply of Maricopa County by storage?

Mr. LOGAN. Practically none. There is no effort being made at storage. It is a matter of grave doubt if the reservoir system here is a practical thing.

Mr. Logan continued his interesting testimony, which is presented in a condensed form as follows:

There is no appreciable difference in the value of cultivated and uncultivated land under the various ditches except there be some valuable improvements in the way of fencing, etc. The value of land not under ditches amounts to nothing at all. There is no cultivation at all except by irrigation.

The general value of land may be estimated at $25 per acre, with water. It is generally considered that land which is tilled, cleared, prepared, ditched, and planted is worth $45 per acre. It is supposed that $25 is bed rock, divided in this way: That $10 is the price of the ditch per acre, $10 the price of the improvement, clearing, etc., and $5 the profit to the investor. Our water system is in good condition, the progress of the country is receiving very fair assistance at the present time, and in the very near future we will make very considerable growth. I presume that of the 5,000 acres in fruit 1,500 or 2,000 acres were planted during 1890. We feel now that railroad communication to the north is possible, if not assured, and we shall have before the end of 1892 10,000 acres in fruit, and the traffic managers assure us that ample transportation will be furnished. There are 700 acres in oranges now. This country will raise peaches, pears, figs, oranges, olives, and almonds. A large majority of our grape acreage is in raisin grapes, and we have reason to believe that this climate will produce superior products in both grapes and raisins. There is no difference in the soil or insects, and a very little alkali is seen along the river bottoms. The water is good for agricultural purposes. It carries an unequaled chemical fertilizer. As to the filling of the land by irrigation and the increase thereby: I came to Phœnix eight years ago. The alfalfa grower told me then that you had to irrigate but once or twice, and seldom three times, per season. Those who irrigate once do it in the winter. We have a good many wells for domestic use in the valley. The experience of the well-diggers is that they find water at from 17 to 25 feet from the surface. It does not all seem to be on the same level. There is apparently an inexhaustible supply at points near the surface. Then at other points they have to go deeper; for instance, at the city waterworks the well is 45 feet deep. As you get back towards the foothills the depth increases, and at points you have to go as deep as 35 feet. That difference in the depths of wells is not due entirely to the altitude of surface. For instance, it is a little deeper to water on Cave Creek than on New River. I think in Cave Creek it runs from 70 to 140 feet, if it is under the canals. The depth in the neighborhood of Phœnix is from 12 to 20 feet. On the other side of the river the depth at Tempe is 5 or 6 feet, and it runs down to 50 feet. The supply of water for domestic and farm purposes is inexhaustible. The use of natural wells for garden or orchard irrigation is limited.

Mr. T. E. Farrish (ex-Commissioner of Immigration for the Territory), made a statement in relation to statistics forwarded to Washington by himself and his son, formerly employed as an assistant hydrographer in the United States Geological Survey. Among these were the amount of land under cultivation in Arizona. It was given by counties and districts. By request Mr. Farrish forwarded a table of persons owning ditches, with the acreage under them, also acres cultivated.

"In that statement I aggregated," Mr. Farrish said, "over 400,000 acres. By an official report I am referring to, the total acreage cultivated is given at 65,821 acres. In a report made in 1889, to the Senate Special Committee on Irrigation, I estimated the amount cultivated in Maricopa County alone, at three times the figures published officially for 1890. As covered by our present canals in this county, there are, according to my estimate, 267,000 acres. My son, Mr. William A. Farrish, was asked for a census report on the county lands irrigated during the fiscal year 1889–'90. His report was 165,000 acres. The total as officially published for Maricopa County is but 35,212 acres. I also notice clear discrepancies in other counties, in all of which I gave the estimate for each of the ditches. In Apache, I estimated 67,000 acres; in Cochise, 23,000; in Graham County I think it was over 13,000; in Pima, 6,000; and in Pinal, 5,000 acres. In Yavapai I do not remember the exact figures, but now estimate the area at 10,000 acres. In my estimate of the reclaimable land and the possibilities of irrigation I held that there could be reclaimed in this county alone about 3,000,000 acres. This, of course, was considering all possibilities of future storage.

"I think my estimate of cultivation by means of water in sight was 1,500,000 acres, with a proper administration of the present supply, and with a successful storage system there could be reclaimed 10,000,000 acres in the whole Territory. In my report for the United States Senate Committee on Irrigation I put the acreage under ditch at 556,560 acres; land requiring no water entered and occupied at 100,000. The number of acres of irrigated land cultivated in 1889 I put at 256,900 acres."

Hon. N. O. Murphy, acting governor of Arizona, submitted the following statement in writing: "There are under the canal system of the Salt River Valley 300,000 acres, and the canals now constructing will cover 50,000 acres more. There are in the Salt River Valley susceptible of irrigation by the extension of the canals from 150,000 to 200,000 more acres. In the Aqua Fria bottoms there are 20,000 more acres, with a possible 30,000, that may be reclaimed by the extension of the canals. In ~~the~~ New River lands, lying northwest of Phœnix, some 30,000 acres will come under cultivation from the proposed reservoir system now contemplated, making an acreage near Phœnix of 600,000 acres.

"There were planted during April, 1890, the following crops:

	Acres.
Barley, including "volunteer"	45,000
Wheat	10,000
Alfalfa	45,000
Orchards and vineyards planted in 1890 and prior	3,000
Orchards and vineyards planted in 1891	2,000
Oranges, including plantation of 1891	700
Sorghum sugar cane, "volunteer" hay, etc	15,000
	120,700

"The yield of crops per acre with good cultivation is—

Barley	pounds	2,250
Wheat	do	1,600 to 1,900
Alfalfa	crops per year	5

"Orchards and vineyards are young and products can hardly be stated. The total yield of barley was, in April, 1890, 65,000,000 pounds; of wheat 15,000,000 pounds.

"A large proportion of this is in 'volunteer,' which must always be considered."

The Chamber of Commerce sent this office the following statement:

PHŒNIX, ARIZ., *November* 19, 1891.

DEAR SIR: Your favor to the Phœnix Chamber of Commerce, dated November 9, is before me with the request that I give the data asked for:

Grain, 58,500,000 pounds	$731,250.00
Alfalfa hay, 263,000,000 pounds	526,000.00
Grain hay, 5,000,000 pounds	25,000.00
Alfalfa pasture, rented for fattening range cattle brought in from the mountains, 25,000 head, at $3 a head	75,000.00
Dried fruit, 1,000,000 pounds	50,000.00
Promiscuous products, such as sorghum, sugar cane, and small fruits	20,000.00
	1,427,250.00

Respectfully yours,

H. H. LOGAN,
Member Chamber of Commerce.
L. J. WOOD,
Secretary.

RICHARD J. HINTON,
Special Agent U. S. Department of Agriculture, Washington, D. C.

Mr. F. D. Trott, Phœnix, stated that four years ago he was in the employ of the Arizona Canal, and there was then more than 40,000 acres under cultivation in the Salt River Valley system of irrigation, which includes the Arizona and Consolidated canals, and that amount has at least doubled. I am sure it is much more than that. There is no quarrel between the corporations and the people. The great majority of the land in Arizona is under the community ditch system, and there could be no trouble. All our water is distributed by a commissioner.

The books of the secretary of the Mesa City Canal Company, exhibited to the agent, show that 223 persons hold shares in that ditch. The total number of shares is 400. Some of the shareholders sublet their water rights, and there are upwards of 300 irrigators under this ditch alone, and a little over 8,000 acres are irrigated.

Herbert M. Wilson, C. E., member of the American Society of Civil Engineers and geographer in the U. S. Geological Survey, stated in a paper read before the society in August, 1891, that the Salt River has flood waters in sight each and every year of from 10,000 to 20,000 second-feet; that the largest recorded flood reached 300,000 second-feet; while the lowest summer flood is placed at 500 second-feet. The Arizona Canal commands 77,000 acres of irrigable land and the Grand and Consolidated canals, under the same ownership, serves 73,000 acres, making 150,000 acres in all, with more than sufficient water in sight every year for the irrigation of about 1,000,000 acres. This is not a matter of storage except as far as conserving the spring floods are concerned. It is not a matter of going into the mountains at high altitudes and storing the possible storm waters there, but of open flowing water, coming annually, and only requiring competent engineering skill and capital to enable it all to be conserved for use in the valley. Mr. Wilson's statement has this importance, that he is, at present, the Geological Survey's expert for all hydraulic engineering possibilities in the arid region.

The admirable works constructed and operated on the north side of the Salt River by the Arizona Company are justly commended in Mr. Wilson's paper. The personal examination made in the summer of 1891, and the personal knowledge of the special agent in charge, dating back to 1877, justifies the statement that the Salt River Valley in Arizona is exceedingly well equipped with irrigation works, well administered, has an abundance of water in sight, and is possessed of a semi-tropical climate and a fertile soil that makes all plant life luxuriant in growth and production.

UNDERGROUND WATERS IN ARIZONA.

Messrs. H. H. Logan and Lincoln Fowler, of Phœnix, two of the most observant and intelligent irrigation organizers in Arizona, in response to questions from the irrigation inquiry, present the following statements.

Mr. Logan writes:

I have studied central and southern Arizona with a great deal of interest for the past eight years, have crossed over almost all of its valleys and mountain ranges, and have examined the districts where the formation changed and contact veins appeared, with a growing interest during all this time. My observation has led me to believe that a large part of central, southern, and western Arizona is in an artesian belt, taking in the district lying east of the Colorado and north of the Gila and Salt rivers.

Arizona, draining as she does all the country lying between the Rio Grande and Colorado rivers—a country enormous in extent (some 600 miles square), much of it being high elevations covered with large bodies of snow during the winter months—and all of these waters passing out of this belt through the channels of the Salt and Gila rivers, shows a surface drainage during the summer months of much less than 1 per cent. I find in many localities under both rivers, within a radius of 100 miles, springs cropping out from the mountains, flowing in many instances several inches of water that are beyond any question artesian in their nature. Take the Caliente Hot Springs on the Gila River, in the western part of Maricopa County, that flow some 500 or 600 inches of water, then follow the water granite formation through any of these mountains at high elevations, and frequently on the tops of ridges where the drainage would be almost entirely away from the surface, are springs of water, usually found in the chimney of water granite. Take the mountains lying south of the Gila: about 12 miles southwest from Phœnix, there are springs along the sides of the mountains that flow small trickling streams of water that is forced up through the seams in the rock. You take it to the north of Phœnix: in the McDowell Mountains, at an elevation of fully 3,000 feet, very close to the summit of the mountains, is an artesian spring that flows some 3 inches of water; it follows up the slate formation that crosses northwest and southeast.

At old Camp McDowell, Mr. Andrews, while there running the pumping station, drilled with 1¼-inch water pipe some 400 feet in the bed of the Verde River; he struck there some three flows of water that raised some 35 feet above the surface of the ground. The well was not tubed, and had passed through very considerable stratas of quicksand, the main deposit being coarse gravel; no rock was struck. The well uncased, simply plugged at the top, raises water some 25 feet, and has flowed a small stream for the last year. The water is very soft and exceedingly pure. This well at McDowell is some 10 miles northeast of the spring in the McDowell Mountains and to the north of this slate formation spoken of as crossing at the spring.

Between Phœnix and the Verde River, at different points, are springs showing the same character of water. Such indications by the way of seepage, etc., are shown on both sides of the Matazal Mountains at frequent points, but almost universally in water granite.

Some 16 miles west of north of Phœnix is what is known as the Beechum well, which, I think, is about 145 feet to water. Lying east of Beechum well, some mile and a half or 2 miles distant, is a sandstone mountain. No moisture was reached in the well until the rock, the shelf of this mountain, was reached. When the rock was uncovered, water running, apparently under pressure, at least that made a noise sufficiently to greatly intimidate the workmen, was heard. The well was not curbed, but was built through a general cemented gravel down to within 5 or 6 feet of the bottom or this rock; it was there curbed and some 3 feet of rock blasted out, when the water rose immediately to the top of the curbing, and has been perpetual for some years, and came in in such quantities that the tools that were used in the last work are still in the bottom of the well.

Take the valley of Cave Creek its entire length, and it is unquestionably in an artesian belt, and probably the same may be said of a large part of New River. The indications point strongly to there being an underpressure, draining, as Cave Creek does, quite a large belt of mountainous country, none of which reaches surface or any possible bed-rock surface drainage for the last 20 miles of its length.

Mr. Lincoln Fowler accompanied the following paper with a Land Office map, on which by numbers is indicated the section he is considering. As it is not desirable to reproduce this, the effort is made to indicate the localities in letterpress. Mr. Fowler says:

Arizona is overdrained in the region of the high plateaus of the north, by the cañon of the Colorado and its lesser tributaries, to such extent that the probability of water being secured from the underflow by artesian wells is very slight. This condition will apply approximately to the northern third of the Territory. The eastern boundary of Arizona follows substantially the watershed of the continent, and at a point slightly north of the center, extending east and west, is the culmination of the plateaus, which are perhaps in reality the southern end of the Sierra Nevada range of California and Nevada. From this crest across Central Arizona, extending southward, are many lesser mountains and hills, and at the southeastern corner of the Territory these ranges extend continuously into Mexico, cut across by the Gila River, in a deep and tortuous cañon, draining from that part the San Simon, Sulphur Spring, and San Pedro valleys.

(The region suggested in the foregoing paragraph by Mr. Fowler, follows on the plateau lines down to and east of the Mogollon range and thence by way of the Chiricahuas and other detached ranges southward into Mexico. Another segment which begins at the southern base of the Francisco Mountain, where the Atlantic and Pacific Railroad crosses the plateau, moves southeasterly along the slope of the Mogollon range into the broad valley or plains south of the Gila River. These valleys and plains are well known as endowed with a large phreatic water supply, lying very near the surface.)

In the San Simon Valley [continues Mr. Fowler] there would seem to be excellent opportunities for artesian wells, as numerous rivulets disappear after leaving the foothills, and many wells are had by cattlemen at depths of from 40 to 80 feet.

The Sulphur Spring Valley takes its name from a group of sulphur springs near the center, and a number of other springs are found at the edge of the plain. There have been a number of artesian borings made, and in several a very good flow of water obtained. A curious circumstance occurred at the time of the severe earthquake of the 3d of May, 1887, when numerous fissures were opened in this valley, from many of which issued running water, thereby proving the existence of underground channels. Another sight then took place, of the cowboys and ranchmen of that section locating, within an hour, on the principal springs for stock ranges, thus availing themselves of the beneficence of Providence at once, regardless of continued tremors. This point was about 100 miles from the center of seismic disturbance, which was in Northern Sonora. Some of the earthquake-developed springs have continued permanently, but most of the smaller ones dried up after a short flow. This valley, some 30 miles wide and 60 miles long, is drained southward into Mexico by the San Pedro River, and thereafter this river turns again into Arizona and runs northward through a narrow valley or cañon to the Gila. The valley of the San Pedro is so slight in width that the river water will probably more than suffice for its development; and it seems unlikely that any expenditure will be made to test the question of artesian flow.

(The central development of springs mentioned by Mr. Fowler is found on the southeast portion of the Caluiro range, at Tres Alamos, and north of Benson on the Southern Pacific Railroad.)

Extending from the Sonora line northward, at about the center of Southern Arizona, is the valley of the Santa Cruz. This stream, rising in high mountains, drains a large area of country with but a trifling surface flow, and for a considerable disance between Tucson and the Gila River, into which it empties, has no surface channel, and in time of flood forms a wide flow through the brush of the plains. There are, however, several places along the underground channel of 75 miles or more, where stockmen and the Southern Pacific Railroad have sunk wells and found uniformly a very good supply of water at moderate depths. So far as the writer knows, no one has ever sunk a cased well on this channel for testing the strength of the flow or if sufficient pressure might be had to cause an actual flow to the surface as artesian water. This would surely be a promising field, for a valley of fertile land, as over one hundred miles in length, awaits the successful issue of such a test.

(The Santa Cruz Valley contains, within from Nogales, on the Sonora line, to Maricopa, near the Gila River, several important settlements and the city of Tucson, the largest in the Territory. There are now over 5,000 acres under cultivation in the drainage basin of the Santa Cruz, while ditches have been constructed to serve about 30,000 acres. There is no reason to doubt that the subterranean flow of the river may be reached and utilized. The number of dug and driven wells already in operation at thriving railroad points, such as Tucson and Casa Grande, are in evidence. Projects are under way looking to retaining the stream flow above by means of bed-road dams, etc., but even then a large supply will find a subterranean course.)

Mr. Fowler calls attention to phreatic water supplies found on the Papagoria, an extensive volcanic plain or table-land with a few isolated ranges lying west of the Santa Cruz, south of the Gila, and east of the Lower Colorado. He says:

> There are in the Quizota Valley and at other points in the vicinity of the Ajo copper mines along the southern border, promising localities of fertile land, needing only water for reclamation, which in the absence of surface flow, except that of torrents, much must be supplied by artesian flow, if at all.
>
> Along the Gila Valley the waters seem to be nearly or quite brought to the surface at many points by the bed rock, which from its character and stratification would hardly admit of the belief that any useful purpose would be served by borings, except on the last 100 miles of its course.
>
> In Southwestern Arizona, but generally to the north of the Gila, the drainage of a large district east of the Colorado from Cullens Valley passes through a defile in the Harqua Hala Mountains and at a lower point through a range of hills is again within a few feet of the surface with indications of a large flow. Between these two points and south of the Harqua Hala Mountains is a very fine tract of excellent land 25 by 50 miles in extent at least, and there would seem to be every reason to expect that artesian flows of water might be had at different points. This would be a great prize to be gained, more than 500,000 acres of land suited to the orange and vine only lacking water. From this valley to the Gila River there is a fine extent of country equal in every way, except size, to the last and overlying the same channel of underflow.
>
> The valley of the Hassayampa, for more than 40 miles, is an admirable field for artesian development, presenting an area of over 200,000 acres, and wholly untried for flowing water, although the configuration of the valley is such that the large underflow which must pass should certainly produce successful results.
>
> Again, in the valley of the Agua Fria, there are evidences of very similar conditions to those of the Hassayampa, with, perhaps, a larger drainage. The valley is of somewhat less extent. No tests have been made, except that near the lower end of the valley, surface wells 40 to 60 feet deep will show a rise of several feet when the covering of the water strata is broken, though no artesian borings have been made.

(The whole area referred to in the foregoing paragraph lies south and west of the famous Salt River Valley at Phœnix to the Colorado River and south to the Gila. It embraces a number of small but fertile drainage basins, small valleys in which some farming is in progress. It is a section of the Territory in which considerable mining is being done, and wherein larger developments are certain to come whenever accessibility to supplies can be assured. The utilization of phreatic waters will materially advance these conditions.)

Says Mr. Fowler:

> In the Rio Verde Valley a small bore was made at Fort McDowell, about 8 miles from the junction with the Salt River, into which the Rio Verde empties. At a depth

Phreatic Waters in Arizona. Wells at Casa Grande.

of 276 feet a flow was found, but on account of the small size of the pipe, 1¼ inches, only a little water was obtained. This might be increased by using larger bores, and the valley is equally promising for a considerable distance. At a place near Pinal two or three small flows were struck at depths of about 100 feet, and in the valley of 250,000 acres lying below, between the Salt and Gila rivers, no one has ever tried for artesian water.

In Arizona between five and six millions of arable land await the husbandman, who is ready when the fertilizing touch of water is to be had; and almost the whole of that vast area is well adapted to oranges, figs, or the choicest vines.

With more than a thousand acres of orange orchards scattered in Salt River Valley about Phœnix, and many times that of raisin and wine vineyards and the finest fig orchards in the West, we may hope for great results.

The artesian wells in the Verde and Sulphur Spring valleys and the Pinal region certainly give assurance that we can expect flowing wells to be had at many points on the known underflow channels yet undeveloped by borings.

The most important of the subterranean stream flows (though not the only one in the Territory) is that of the Santa Cruz River. It is so peculiar and significant in character as to warrant a description of its features. It rises, then, in the southeasterly corner of Pima County, Ariz., about 20 miles north of the Sonora State line, Mexico, and courses nearly due south, crossing the Arizona line into Sonora some 18 miles, makes an elbow and reënters Arizona not far from Nogales on the Mexican frontier. The course, then, of the river is northwest to Calabasas and Tubac, and thence nearly due north to Tucson; from that point its course is northwesterly to a junction with the Gila River near the Maricopa Wells. The river is in some respects a phenomenal water course, being at times a stream from a few feet to a quarter of a mile wide with a depth of but a few feet to sufficient to float the largest Mississippi River steamboat.

The contour of the watershed of the main stream and its branches is very irregular, and the drainage area may be roughly estimated at 7,500 square miles. From its source to Tubac the stream is quite large and shows a dry season surface flow varying from 2 to 10,000 inches. From Tubac to San Xavier del Bac (Papago Reservation) most of the water course is subterraneous, and thence to Point of Mountain, 18 miles below Tucson, the flow alternately appears and disappears. From Point of Mountain to the junction with the Gila River it practically disappears and is an underground river, its course in many places and for many miles being traced by a belt growth of mesquite trees from 500 to 2,000 feet wide. The hydrographic physical features of the valley are little understood. Underlying the valley is an almost continuous body of coarse gravel, through which water percolates to an unknown depth. It has been tested at Tucson to a depth of 52 feet, all in this water-bearing material, and an estimate approximately made covered a width of from 1,000 to 4,000 feet, and to the depth tested, allowing only one-tenth of the area for water, percolation would bring some 370,000 irrigating inches every twenty-four hours. Add to this the enormous quantity that could be stored in great catchment reservoirs from two rainy seasons—winter and summer—and the possibilities can be better seen of the importance of this region. Another extensive drainage supply could be taken from the Pantano cienego region, known as the Rietta Creek, 22 miles easterly of Tucson, a branch falling into the Santa Cruz, about 6 miles below Tucson. To the casual observer passing through this country upon the railroad it has the appearance of being a worthless, more than semi-desert, region. By proper treatment and intelligent engineering skill it would soon compare in crops and food products with other accepted sections of great richness and importance in the variety and abundance of its products.

As to other evidence, Capt. W. P. Williams says that with a Worthington pump he gets 200 inches of water within 1 mile of Maricopa. Capt. Henry Arey, of Maricopa Station, said:

> In order to get parties interested in land around Maricopa Station, I had a well sunk at a cost up to date of $5,000. The plant is a Worthington pump and reservoir with a capacity of 2,000,000 gallons. The well is sunk in what is supposed to be the lost bed of the Santa Cruz. It is 58 feet to bed rock, and there are 13 feet of water in the well. Two acres were put in late last year, but the pump was not ready until March—too late for this crop. My opinion is that the Santa Cruz flows along the bed rock; and that while $2.50 per inch is charged for water from the ditch I can pump it from the river for $1.25. By drifting out from the well chamber into the bed of the Santa Cruz I can at least double my supply and perhaps do better. The well can not be cut off.

The Southern Pacific is digging another well in the neighborhood and gets water at a depth of 45 to 50 feet. They also think the water comes from the Santa Cruz. The strata gone through are red loam, sand, then a cement that had to be blasted through for 16 to 17 feet, then loose gravel in the bed of the Santa Cruz for a distance of 30 feet, and then down to bed rock. The water chamber of the well is 10 by 10 feet, and the river flows right through it from northeast to southwest.

An hydrographic study of the Santa Cruz Valley, especially that portion from the Sonora line to Point of Mountains, a distance of some 90 miles, leads to the conclusion that by developing and husbanding the underflow of this great drainage basin the greater part of the arable area within these boundaries could be irrigated. The Valley from Nogales to Tucson is a rich soft loam, capable of producing a great variety of agricultural products and fruit. At San Xavier a rock barrier has been thrown across it by volcanic action, producing a narrowed gorge, where a catchment dam could be built to bed rock and impound an immense body of water. This place is known as the Punta de Agua (place of water). Thousands of acres of fine land could be successfully irrigated from this great natural reservoir. The site of this dam is on the Papago Indian Reservation, and the contour overflow lines would fall partly into the reservation and partly outside. This importnt a location can not be used until action is taken to free the site from connection with the reservation. The Indians make very little use of the water, and have allowed the fine farms below it on the reservation to lapse into a wild growth of weeds and disuse. Turned to civilized uses it would be of vast benefit to Tucson and furnish water to a great number of settlers.

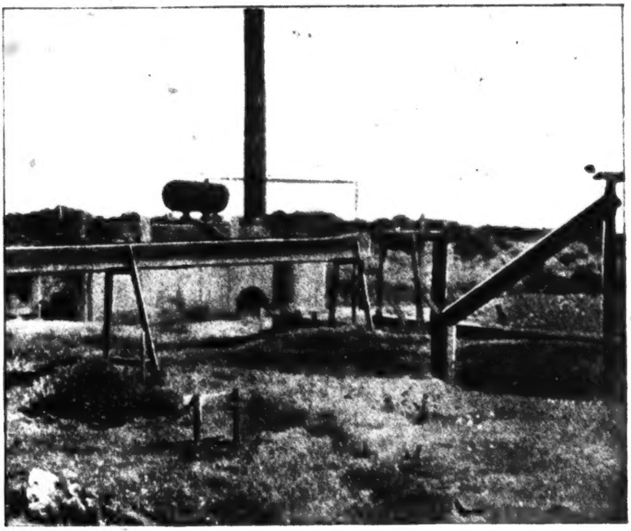
ANSWERS FROM CORRESPONDENTS.

The following summaries are made from replies received to circulars sent by this office:

APACHE COUNTY.

Snowflake (post-office)—Jesse N. Smith (October 5, 1891):

Water supply, Silver Creek. Large supply winter months. Small supply in growing season.
Irrigation Works—Four main ditches, aggregating 15 miles in length, about 7 feet on top, 5 feet on bottom, one main headgate for each ditch. "Two reservoirs, area three-quarters of a mile and 2 miles."
Cost of ditches per mile, about $500.
Cost of reservoirs, $1,500 and $2,500 respectively.
Average cost per acre of irrigation works, ditches, etc., about $12.
Average cost per acre for preparing land for cultivation by irrigation, about $10.
Average cost per acre for annual maintenance and repairs, about $2.
Staple products under irrigation, and average value per acre, wheat, $24; corn, $20; oats, $20; alfalfa $30; potatoes $40.
Area under ditch, 3,000 acres.
Area under cultivation, 2,300 acres.



Raising Water from a Lost River. Well with Worthington Pump in Bed of underground Rio Santa Cruz. Near Maricopa, Arizona.

COCHISE COUNTY.

[Data compiled from or report made by the board of county supervisors to a United States Senate Special Committee on Irrigation, in 1889. Area of county, 6,972 square miles. Three principal valleys are mentioned, viz, San Simon, Sulphur Spring, and San Pedro.]

San Simon Valley (in eastern portion of county)—watered by San Simon Creek, which has a drainage area of 144 square miles. "Soil of valley in many places being sandy, this stream runs underground, and comes to the surface at points only where the clay bed or bed rock comes near the surface, at which points an abundance of water is shown; greater part of valley could be irrigated and made very productive could these waters be utilized;" but little irrigation in valley; only about 2 miles of ditches; not exceeding 300 acres in cultivation; susceptible of cultivation, 6,000 acres. (The first artesian well obtained in Arizona was in this valley, in 1882, of which there are now quite a number.)

Sulphur Spring Valley (through central portion of county) lies between several ranges of mountains on its east and west sides; drains an area 30 miles wide and 90 miles long. "The waters of this valley flow southerly into Mexico, and form the headwaters of the Sonora River. Waters of this valley also flow underground, forming an abundant supply but a few feet from the surface. Not over 4 miles of ditches in valley; about 2,000 acres under cultivation in valley and foothills adjacent; susceptible of cultivation by irrigation, 200,000 acres.

San Pedro Valley (in western portion of county) lies between ranges of mountains, and is watered by San Pedro River, which rises in Mexico and flows northerly through this county and empties into Gila River in Pima County; river has a watershed in this county of 25 miles in width by 80 miles in length, and a total watershed (including that in Mexico) of 2,700 square miles, the waters from all of which pass through this county. This valley also has "a large under ground current," rising to the surface at intervals, as in the other valleys; valley quite thickly settled; about 40 miles of ditches; all main ditches supplied from main stream of river, by means of brush and earth dams usually (sometimes by dams made by sacks of sand) diverting water into ditches. Dams washed away by every flood. Lands under cultivation, 6,000 acres; susceptible of cultivation by irrigation, 50,000 acres. (The lower part of this valley presents a promising field for the development of an artesian supply for irrigation.)

There are many large springs in the county which might be utilized to irrigate orchards and vineyards in the foothills and higher table lands. Some of them are now used by means of ditches to irrigate vegetable gardens and orchards, and some by means of pipes are utilized for the watering of stock. Certain reservoir sites are designated by the board and their construction recommended. (Great progress has been made since the date of this report throughout the county.)

GRAHAM COUNTY.

Safford (post-office), E. D. Tuttle (September 27, 1891):

Water supply: Gila River, stream large in spring but small in July and August; large underground stream, the river sinking and rising to surface at intervals of a mile or thereabouts where dams are made and canals taken out.

Works: Between the Narrows (8 miles east of Solomonville) and Fort Thomas (38 miles west) there are 20 canals, averaging 8 feet wide on bottom, 10 to 12 feet on top, "with average depth after reaching surface of 3 feet in the soil;" length from 2 to 8 miles with average grade of 4 feet per mile. Each canal has head and waste gate, with simple distributing gates for each farm. Canals all dug and maintained by owners of land irrigated. The laterals are easily and cheaply made. Lands have a generally even and gradual slope. The dams are only temporary.

Area under ditch, 50,000 acres, approximately.

Area under cultivation, 15,000 acres.

Cost per mile of ditches, $500, average; cost of water to user per acre, $2.50; no rental of water.

Average cost per acre for preparing land for cultivation under irrigation: Bottom lands along Gila River, from 1 to 2 miles in width, and auxiliary lateral valleys are covered with mesquite and sagebrush; cost of clearing this about $5.

Cost of annual maintenance and repairs: About 30 per cent of first cost of canal. This cost is largely out of proportion to the first cost of the canals, etc., on account of the floods that tear out the headworks, carry away the dams, and fill canals with silt or mud.

Staple products under irrigation: Alfalfa, corn, wheat, barley, oats, sorghum, potatoes, beans, etc. (alfalfa is the principal forage crop, giving five cuttings per year, and giving pasturage all winter).

Average value of product per acre: Alfalfa, $20 to $25, gross; small grain and corn, about $15.

MARICOPA COUNTY.

Phœnix (post-office), H. H. Logan (September, 1891):

Salt River Valley (600,000 acres): Water supply, Salt River.

Works: Ten main canals (about 300 miles); from 15 feet to 36 feet on bottom; carrying from 3 to 7½ feet of water; laterals, over 5,000 miles; no reservoirs; only 1 dam on Salt River which is 945 feet long, raising the water 8 feet; 10 headgates.

Area under these 10 canals, 300,000 acres; under cultivation, 145,000 acres.

Average cost per acre in the past for irrigation works, probably $5.50 to $6.

Average cost per acre in the past for annual maintenance and repairs, 60 to 75 cents.

Average cost per acre in the past for preparing land for cultivation under irrigation: For clearing, bordering, and ditching, about $2; for putting it into grass, about $5 additional.

Cost of water supply to user per acre, average $10; annual rental, $1.

Staple products under irrigation: Wheat, barley, alfalfa, sorghum, sugar cane, apricot, peach, prune, pear, fig, grape, nectarine, orange, and lemon; all staple vegetables grown during the entire year.

Average yield per acre: Wheat, 1,700 to 1,900 pounds; barley, 2,200 to 2,500 pounds; alfalfa, 8 tons; sorghum, 30 tons. No reliable data of fruit yield, except the raisin grape, 7 to 10 tons per acre on 3-year-old vines.

Phœnix (post-office), Lincoln Fowler (September, 1891):

Grand, Maricopa, and Salt River Valley canals: Water supply, Salt River; capacity, from 350 cubic feet per second, upward.

Works: Grand Canal, 24 by 4 feet, 35 miles long; Maricopa and Salt River Valley canals, joint head, 24 by 4 feet; ditches 50 miles long. Headgates: Grand Canal, 100; Maricopa and Salt River Valley canals, 75.

Area under ditch, 50,000 acres; under cultivation, 30,000 acres.

Cost per mile of canals, etc., $500 to $10,000.

Average cost per acre for irrigation works: Canals, ditches, etc., $10.

Average cost per acre for preparing land for cultivation under irrigation, $2.50.

Average cost per acre for annual maintenance and repairs, $1.25.

Cost of water supply to user per acre, $10.

Products under irrigation: Alfalfa, wheat, barley, oranges, grapes, peaches, and other fruit.

Average value of product per acre, from $15 to $250 (wheat and barley, $20; alfalfa, $30).

Tempe (post-office), E. G. Frankenberg (October 17, 1891):

Tempe Canal system: Water supply, Salt river; supply insufficient in summer.

Irrigation works: Water diverted by two brush and rock dams, tightened with sand and gravel, by one into an old channel of river, by other into canal proper. Main canal 1¼ miles long, 28 feet on bottom, 40 feet on top; two branches 5 and 8 miles long; also southern extension 23 miles. (Laterals not included in above.) One main head gate; also one at head of each branch; two waste gates and ditches returning water to river.

Area under ditch, 25,000; under cultivation, 22,000 acres.

Cost per mile of works, main canal, $25,000; first branch, $1,000; second branch, $800; southern extension, first section, $1,375; second section, $750; third section, $500; fourth section, $350.

Average cost per acre for ditches, etc: For main canal and branches, $2.75 to $3; for laterals and distributing ditches, $1 to $3.

Average cost per acre for preparing land for cultivation under irrigation: For grain raising, from $2.50 to $3; for alfalfa grazing land, $3 to $5; for fruit culture, $5 to $15.

Average cost per acre for annual maintenance and repairs: Main canal and branches about 50 cents; laterals, etc., 25 to 75 cents.

Chief products under irrigation at present, wheat, barley and alfalfa. In the near future fruit culture will be the principal occupation of the land owner; as the climate and soil of this valley are especially adapted to the growing of oranges, raisins, peaches, apricots, figs, nectarines, dates, plums, pears, etc.

Average yield of product per acre: Wheat, 1,500 to 2,000 pounds; barley, 2,000 to 2,500 pounds; alfalfa, 3 to 8 tons can be cut monthly.

[Mr. Frankenberg states that he gathered 9 tons of peaches per acre; 500 pounds of raisins per acre from 2-year-old vines; 6,400 pounds of almonds per acre; 8 tons of wine grapes per acre, from 8-year-old vines.]

Mesa City (post-office), C. I. Robson (October, 1891):

Water supply, Salt River; when river is full 8,000 inches are used; present supply, 2,000 inches (October, 1891).

Works: 10 miles main canal; 23 feet on bottom; bank slope, one to one; no reservoir; dam one-half mile long; average height, 5 feet; one main head gate; one waste gate or overflow.

Area under ditch, 8,000 acres; under cultivation, 4,000 acres.

Cost of main canal per mile, $5,600.

Average cost per acre per canal, etc., $7.

Average cost per acre for annual maintenance and repairs, $1.50.

Average cost per acre for preparing land for cultivation by irrigation, $2.50 (average)

No rental of water; water users are owners of works, etc.

Staple product under irrigation, grain, hay (alfalfa), and fruit.

Average yield of product per acre: Grain, 1,500 pounds; alfalfa, 5 tons; value of fruit yield per acre, $50.

MOHAVE COUNTY.

C. M. Funston (Kingman post-office), and W. G. Blakeley (Mineral Park post-office).

About 80 miles south of Kingman there are irrigation ditches (probably 20 miles), none exceeding a mile in length; mostly crude and small; owned by farmers; water supply, Sandy River and spring.

In vicinity of Mineral Park "no land is cultivated except little garden spots, watered by small springs or wells on premises; mining chief industry."

Area under ditch in county, about 1,000 acres.

Area under cultivation in county, about 800 acres.

"Very little produce raised, but cereals, fruits, and vegetables could be successfully grown with proper irrigation facilities."

PIMA COUNTY.

W. A. Hartt (18 miles south of Tucson):

Reports water from well located in Santa Cruz Valley; well 4 by 4 feet, raised 60 feet by compound pumping engines; continual capacity, 2,500 gallons per minute.

Works: 3 miles main ditch, 4 feet on bottom, 12 feet on top, 3 feet deep; about 15 miles laterals. One reservoir (storage), capacity 200,000,000 gallons; supplied by surface or flood waters. One distributing reservoir, 7,000,000 gallons; other works, one pulsometer pump; capacity, 1,000 gallons.

Area under ditch, 1,920.

Area under cultivation, 600 acres.

PINAL COUNTY.

Kenilworth (post-office), Thomas W. Graham (October 14, 1881):

Water supply: Gila River, through Florence Canal. Plenty of water in river, but poorly constructed canal.

Works: Canal 40 miles long, 18 feet wide on bottom, all dirt work. One reservoir, area 1,800 acres; will hold 4 feet of water. Head gate destroyed by flood last February; not rebuilt by company.

Area under ditch by this system (Florence Canal), 100,000 acres.

Area under cultivation by this system (Florence Canal), 10,000 acres.

Cost of water to user per acre, $8 (water right, this system).

Annual rental cost $1.25 per acre.

Average cost per acre for preparing land for cultivation under irrigation $5 to $10 (high or mesa land costs less than river-bottom lands on account of less growth to be removed or cleared).

Chief products under irrigation: Alfalfa, barley, wheat, apricots, grapes, and figs.

Average yield per acre: Alfalfa, 4 tons; wheat and barley, 1,500 pounds.

[Mr. G. states that he is unable to estimate the cost of works, ditches, etc., or maintenance and repairs; this can only be obtained from company.]

YUMA COUNTY.

Chrystoval (post-office), O. F. Thornton, president South Gila Canal Company (September 26, 1891):

Water supply, Gila River (near Oatmans Flat, Maricopa County).

Works, 22½ miles of ditch, 12 feet on bottom, 20 feet on top (to be used as lateral after completion of canal); one head gate; no reservoirs.

Area under ditch, 18,000 acres (when main canal is completed there will be 130,000 acres).
Area under cultivation, owing to floods last season, and this being a new country, very little land cultivated.
Cost per mile of canal, $2,000.
Average cost per acre for canals, etc., $5 to $10.
Average cost per acre for preparing land for cultivation under irrigation, $5 to $25.
Average cost per acre for annual maintenance and repairs, not less than 25 cents.
Cost of water supply to user per acre, $1.50.
Products, wheat, barley, Egyptian corn, alfalfa, sorghum, beans, etc.
Estimated value of product per acre, $25.

Mohawk (post-office), George W. Norton (September 25, 1891):

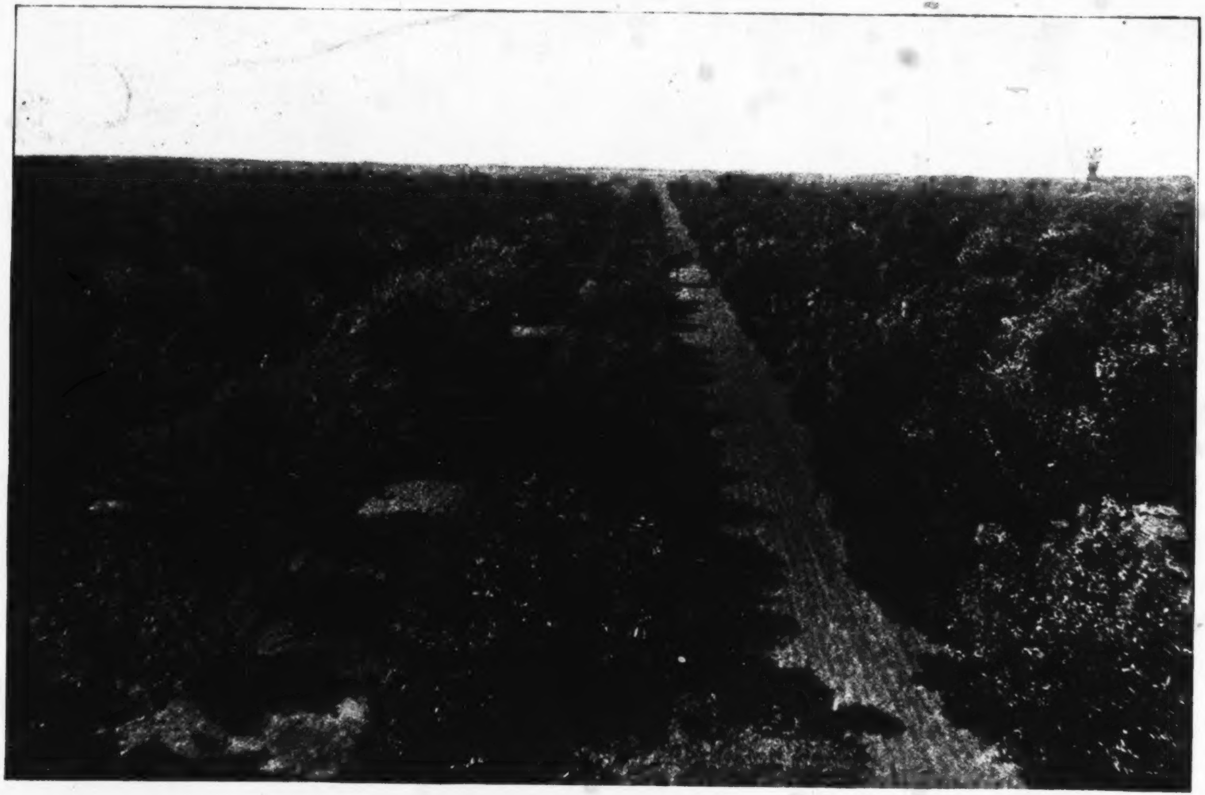
Mohawk Canal water supply, Gila River at Texas Hill; capacity of canal, 10,000 inches.
Works, 33 miles canal, 14 feet on bottom for 8 miles, slope 2 to 1; remaining distance, 10 feet on bottom, slope 2 to 1; one head gate; no other works.
Cost of canal, $150,000.
Area under ditch, 30,000 acres; under cultivation, 10,000 acres.
Average cost per acre for irrigation works, ditches, etc., about $10.
Average cost per acre for preparing land for cultivation under irrigation, about $20.
Average cost per acre for annual maintenance and repairs, about $5.
Cost of water supply to user per acre, $10; annual rental cost, $1.25 to $2.50.
Chief products under irrigation, vineyards, wheat, barley, alfalfa, etc.
[Country too new to estimate average yield or value of product.]

Palomas (post-office), A. E. Martin, president Farmers' Irrigating Canal Company (September 28, 1891):

Water supply, Gila River; 5,340 miner's inches for canal.
Works, 18 miles canal; first 6 miles 10 feet on bottom, 19 feet on top, 3 feet deep; second 6 miles 6 feet on bottom, 15 feet on top, 3 feet deep; last 6 miles 4 feet on bottom, 13 feet on top, 3 feet deep; one head gate; no reservoir or other works.
Area under ditch, 4,800 acres; under cultivation, 590 acres.
Average cost per mile of canal, etc., $1,611.11.
Average cost per acre of canal, etc., $6.04.
Average cost per acre for preparing land for cultivation under irrigation, $1.87.
Average cost per acre for annual maintenance and repairs, $9\frac{6}{10}$ cents.
Products under irrigation, wheat, barley, corn, sorghum, alfalfa, and garden vegetables.
Average yield of product per acre: Wheat, 50 bushels; barley, 55 bushels. Two crops per year are raised. Wheat and barley first. Then corn and sorghum.

Yuma (post-office), F. S. Ingalls (September, 1891):

Water supply, Colorado River.
Works, steam pump, 6,000 gallons per minute; 3 miles of ditch, 14 feet wide on top, 10 feet on bottom; no reservoir or other works.
Area under ditch, 3,000 acres; under cultivation, none at present.
Cost per mile of works, ditch, etc., not to exceed $300.
Average cost per acre of irrigation works, ditches, etc., about $5.
Average cost per acre for annual maintenance and repairs, nominal.
Average cost per acre for preparing land for cultivation under irrigation: Clearing, $2.50; leveling and ditching, $25.
Cost of water supply to user per acre and rental cost, not yet fixed.
Products, no data.



Irrigated Orange Orchard at Los Angeles, California.

CALIFORNIA.

In dealing with the climatic conditions of California, and (so far as related thereto) of Nevada, as connected with irrigation, Lieut. Glassford, Signal Corps, U. S. Army, now in the Weather Service, Department of Agriculture, has presented in the report ordered by Congress, an interesting theory of climatology which has much to recommend it to consideration. Examination testifies to the accuracy of the statement that "two influences dominate the climate of California, radically dissimilar in every particular, combining in ever-varying forces to produce the resultant which is recorded by observers of the weather. One is the sea tending always to charge the air with moisture, the other is the mountain mass tending always to discharge the moisture from the air. The combination of these two activities in varying proportions is responsible for the variation in the amount of precipitation."

It is necessary of course to consider both of these influences. The topographical factor comes first. The chief mountain formation of the two States includes "the maximum extension in latitude of the Cordilleran system." The "characteristic orographic feature" of the region is the Sierra Nevada, and it is also "the predominant" climatic instrument, both for California, to which it gives the rain, and for "Nevada, from which it withholds" the same. The Sierra Nevada itself is about 600 miles from north to south. The northern extension of the range, the Cascade Mountains in Oregon and Washington, have a lineal extension of nearly 700 miles. The culminating center of the Sierra Nevada is Mount Whitney, towering 14,898 feet above the sea, in the San Joaquin Valley. The general elevation is carried from that mount northward for over 100 miles at about 11,000 feet. Southward it descends to about 8,000 feet. Lake Tahoe, to the north, is just below the 9,000 feet contour, and beyond that, after the Central Pacific Railroad crosses at about 7,000 feet, the range rises again to Shasta, with a general elevation of about 8,500 feet. Below the San Bernardino Range the Caccopah Range breaks down in the Colorado Desert to an altitude of about 5,000 feet. The western slopes of the Sierra are scored with deep and precipitous cañons, and are marked as they descend into the deep troughlike valleys of the San Joaquin and Sacramento, with a wide area of rugged foothills. The total length of this portion is 400 miles, varying in width from 40 to 70 miles, where the western rim is made of the Coast Range. It is said—

> The eastern limit is fixed with considerable precision of definition at a practically constant distance from the western limit of the Sierras, the expansions are uniformly made by encroachments upon the sea. The system comprises a multitude of subordinate ranges, some large and some small. * * * The general trend of the subranges as of the system at large is with a tendency toward parallelism with the coast.

The parallelism with the greater Sierra Range is complete. The northern and southern extremities of the Coast Range unite or swing in upon the great valley.

And so enter upon the vaster mass and elevation, to the north at Shasta and to the south in Kern County. Geological conditions alone indicate the primary divergencies of the two systems. Below the Tehacapi Range, it is not quite possible to distinguish, except as to the San Bernardino Range, whether the broken formations are to be classified with the Sierra or the Coast Range. Nevada may be described generally as within the Great Basin region. The western section of course lies more directly under such climatic influences as rise from the eastern slopes of the Sierra Nevada. For the purposes of cultivation by irrigation the great interior valley formation of California is the most important. With the certain growth of the district system, insuring as it does security for investment and safety for water control and administration, the Sacramento and San Joaquin valleys are to become more rapidly the acme centers of irrigation industry. Elsewhere in the Golden State, special localities, each perhaps limited in area, but most valuable for special crops and products, will occupy a large share of public interest, but the valley or plain which lies between the Sierra Nevada and the Coast Range, east and west, and the Shasta and Tehacapi cross ranges north and south, will be the dominant agricultural region; as in part for vines and desiduous fruits, it will also be the center of horticultural and viticultural activities.

Between the great mountain walls indicated, this vast troughlike plain has a length of about 450 miles and maintains the average breadth of 40 miles, taking in the lower foothills so far as they are available for agriculture, and thus contain some 18,000 square miles or 11,520,000 acres. The only breach in its mountain wall is at San Francisco, midway of its length, and at the water level this gap is less than a mile wide. The vastness and majesty of the mountain formation is no more significant than its simplicity. The nature and character of the "oceanic factor" in the Pacific coast climatology is equally as well marked by these two massive and cosmical features. The Pacific, which is the largest mass of oceanic waters, is also the least subject to disturbance or perturbations.

Mr. Glassford says:

Its conditions are constant over large areas, its currents both of wind and water are drawn in broad sweeping curves in which extent of space and time of passage serve to override all mere local or temporary modifications. Thus it is enabled to present almost the ideal problem of oceanic circulation and to array upon the climate of California, and in a modified degree upon that of Nevada, a few simple influences which become involved and difficult of study only through the continental disturbances.

That part of the Pacific Ocean which is related to the California coast stretches westward for nearly 100 degrees of longitude, with its farther horizon above the Chinese Sea, and its northern and southern extremities at the Aleutian and Philippine Islands, respectively. No land mass borders on the southern rim of this oceanic plain, while at the north are found the peninsula of Alaska and the Aleutian Islands, yet the meteorological distinction between the North and South Pacific is clearly defined at both borders. For its effect on our climate—

It exists at the thirtieth parallel of north latitude. Below this bounding line is the region of the northeast trade wind and the west drift of the equatorial current and these two serve sufficiently to bound in wind and water the great basin above.

It is a basin within these limits, a rough ellipse having a major axis of 100 degrees of longitude and a minor axis of 25 degrees of latitude. It has its characteristic system of circulation both of atmosphere and sea. The strongly individualized ocean current of the region is the Kuro Siwo. Developed from the cumulative progress of the equatorial drift and directed by the alteration in the plain of the sea bottom and the trend of the Asiatic coast this warm stream moves across the whole northern Pacific. Occurring in a broader sea it shows several important differences from the Gulf Stream, it has a slower motion, its warmth is not so strongly contrasted with the water through which it flows, and the wind blowing counter to its course frequently avails to deflect it or even check it entirely.

Whether or no this current reaches the Californian coast is still a matter of discussion among physicists. But "the winds upon this basin are of the system of the passage winds which are developed upon the surface of the earth by the descent from high altitudes of upper currents. In general these winds vary with the latitude from southwest westerly to northwest. It should be noted that these winds begin to appear about the parallel of 30 degrees north and that at first they are practically dry winds, but presenting all the best conditions for absorption."

Mr. Glassford's review of what he technically terms "passage winds," in connection with Pacific oceanic influences, demands careful study. The phenomena he presents make a very important segment of those which control the arid conditions of all our Cordilleran areas. The local use on the coast of the term "trade wind" is deprecated by the Weather Service writer as both misleading and too narrow. He says:

> These passage winds have a clear sweep across many thousands of miles of sea, and in all this course they incur no resistance save such as is caused by convective friction due to varying amounts of pressure within their mass. But the moment they ceased to flow over the sea and begin their course over the continental mass they are subject to violent perturbations and present all the features of turbulent motion, its irregular and rapid changes of pressure, its rapid expansion, its sudden alterations of the saturation constants, and variations of temperature. These perturbations must be examined in the light of mountain influence in general.
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> The wind drawn in from sea by the general circulation of the atmosphere may be taken to have in suspension the maximum amount of moisture, and * * * to approximate the saturation amount theoretically to be expected in air of a given pressure and at a given temperature. * * * Variations in pressure and temperature caused by possible distant commotions of the atmospheric envelope may change these amounts. Advancing upon the land the air current immediately encounters perturbing influences * * * such as friction upon uneven surfaces, convection caused by radiation from irregularly heated bodies, and vortex motion within the stream.

These are liable without regard to surfaces. There are also perturbations due to planes which are at a considerable angle with the horizon, and in addition there are the development of pressure by transformation of the impact of the air current upon the elevating plane, the loss of temperature by elevation, the alteration of pressure, and the expansion due to the same cause and the great diminution in the amount of water which may be held suspended. "There is further to be taken into the count the variation of the mountain influence, due to alterations in its radiation of heat. This variation is seasonal. It is due largely to the existence and the melting away of snow bodies. In the first place "the disturbances are at their minimum and so is the precipitation." With the melting of the snow the exposed mountain surface becomes absorbent, and therefore an active radiating agent. "The air current becoming violently involved, is suddenly drawn to great height by updrafts." Then its excess of moisture is 'wrung out' by ensuing expansion. When this sets in on the Sierra Nevada it is dependent upon the sun's southerly movement with such local modifying forces as may be ascertained. The great valley is one of the primary disturbers in the passage of the air currents over the Coast Range from the ocean to the Sierra Nevada. An aërial column moving horizontally against a vertical barrier, that is, a mountain mass, would naturally divide right and left when it had reached and commenced its movement along the face of the barrier. In this way the great valley obtains the circulatory air currents which is one of its special features. These eddies and whirls produced by the impact with the mountain slopes and summits largely distribute precipitation, making a windward fall. That to the leeward of the range is determined by the rise of the currents and their passage over the ridges. In other words, according to Mr. Glassford:

> On the weather side of a high mountain range the moisture is largely precipitated before the elevation of the summit is reached and thus there is absolutely little left to drift over on the leeward side. The second fact is that the small amount of rain which is condensed at altitudes sufficiently high to allow it to drift past the condensing summit is subjected to influences which have a tendency to still further reduce its amount as to falls. * * *

The Pacific Ocean "passage winds," before being drawn to the surface at about the thirtieth parallel of longitude, have held their course in extreme upper atmospheric conditions, where "excessive cold and tenuity have served to remove their vast humidity," so that when they come to the ocean's surface they are practically desiccated. The moisture they then receive comes from the ocean itself.

Mr. Glassford says:

> The sea is warm and in the best condition for giving off moisture, the wind is most receptive and the amount of humidity which it will assume is mainly conditioned by the distance through which it passes over water surface. In the region where the wind prevails with southwestern inclination this distance may be easily determined and will serve as a means of comparing the average amount of moisture received by places on the Pacific coast.

The theoretical consideration presented by the Weather Service writer, is that a dry wind will assume a certain proportion of moisture from every mile of water surface traversed." Though an efficient general rule, it is, like all meteorological conditions, liable to be affected by local and temporary factors. Still, the records of annual precipitation show that the general principle stated exercises a steady influence. The local and temporary are naturally obliterated in long-time charts, while the general and secular remain as the marked results of the North Pacific passage wind. Mr. Glassford tabulates five coast stations, San Diego and San Francisco, in California, Westport, Columbia Bar, and Tatoosh to the north. Their latitude and relations are, respectively, 33 degrees N., 252; 38 degrees, 672; 40 degrees, 846; 46 degrees, 1,350; 48 degrees, 1,524. The "humid constitution" of the winds are given. For San Diego, annual rainfall measured 10.26 inches; San Francisco, 23.80; Westport, 37.84; Columbia Bar, 67.68; Tatoosh, 94.42. There is an excess between the measured and "theoretical" rainfall, that is, the amount as estimated by the traveled space of the passage wind; (excluding San Diego), as follows: 3.49 inches, 3.36, 12.69, 32.45. The increment is observed to be progressive with increase in northern latitude. The fact is of considerable significance, but the materials for determining its causes are very scanty.

> But [continues the expert] one thing is certainly known because universally observed, and that is, that within the zone of the passage winds across the great ocean the wind hauls westerly in close ratio to the latitude. The wind which moves the rain upon the northern Pacific coast is then not rigidly a southwest wind, it blows from nearer west, traverses more water, absorbs more moisture, and precipitates more rain, and this is a factor of progressive increment to the north and capable of producing an influence of perturbation. * * *

The curves from 55-inch to 90-inch are all defined in the extreme northern section. The 55-inch affects portions of Shasta to Sierra County and then crosses westward, entering the sea to the north of Mendocino. The 60-inch curve enters by way of the Klamath Valley from Oregon and passes out at Trinidad Head. The highest curve, 90, is directly caused by the presence of Shasta, and with those of 82 and 87 affects the areas just below the mountain and passes out to the sea about Crescent City, on the coast. As Mr. Glassford expresses it, from these summaries "it will appear that the least rainfall is upon the Colorado Desert in extreme southeastern California, and the greatest is correspondingly extreme in the northwest; that Nevada, the Great Valley, and the southern coast are the regions of insufficient rain; that the fall increases progressively with height upon the Sierra Nevada, less distinctly so upon the Coast Ranges, and upon the northern coast the increase is more with latitude than altitude." One notable phenomena needs referring to. It is evident that the powerful Cordilleran influence, which, as "guide planes" for aqueous atmospheric currents, must so powerfully affect precipitation and distribution, are yet without effect at certain maximum periods. This is notably true of California. The weather-service writer says:

> The only explanation possible is that the air thus elevated is too dry to precipitate moisture; that its absolute humidity is so low that when the mountain has cast it up to the greatest height within its chimney of convective influence, when it has reached the lowest temperature, the lowest pressure and the highest degree of expansion, the humidity is still below the saturation point predicated on those factors, and no precipitation can occur nor even a cloud form, and those who, from the parched and baking valleys, look toward the shining Sierras, know that the white cap is snow, not cloud. This influence, then, is permanent; the change is in the moisture of the air. Yet as there is equal permanence in the power of dry air passing over leagues of sea to absorb moisture, it is not supposable that this natural force is extinct during certain months of the year and efficient during certain other months, for nature does not thus sport with her fixed laws. It is clear that the moist winds and the desiccative mountains do not come together; thus some cause in nature intervenes to keep them apart during the dry summer of the Pacific slope and the more immediate region of the Great Basin.

As to the nature of this cause, Mr. Glassford offers the following:

> Four points are found to be correlated in a mutual influence upon the climate of the continent, three are always apparent, the fourth is sometimes indefinite in either ocean or the regions north and south, where no meteorological stations are situated. These four points are two areas of low barometer. Their positions relative to one another and to the earth beneath determine the climatic conditions of any periods, be it day, week, month, or year. In one group of positions of these four points the storms have an easy sweep to bring rain across the country, in another group of positions every obstacle is put in the path of storms.

These groupings are defined as to "high" and "low" barometers in the annexed concise descriptive paragraph:

> Over every point of earth stands an air column of uncertain height. The weight of this column of air is registered by the barometer, and from the weight an idea is obtained of the height. A high reading of the barometer at the earth is the surface indication of a high air mass overhead. By grouping these surface indications it is possible to form an idea of the upper of the air with high peaks and ridges over the areas of high barometer on the earth and valleys and depressions corresponding to the areas of low barometer. In effect a barometric high indicates a atmospheric mountain, the steepness of whose slope is exhibited by the close or diffuse assemblage of lines of equal pressure, and the barometric low as surely indicates an atmospheric currents which always seek the line of least resistance and therefore must flow in atmospheric depressions. The leeward side of such an air mountain must then be a place of security against the storms, a region of clear weather, and such it is found to be.
>
> The general movement of the storms is known to be easterly; if the valleys extend east and west the storm has a free passage and converts none of its force by beating against obstacles; it carries its severity to all parts of its course. But, revolve the axis of the atmospheric convolutions through 90°, place the ridges of high elevation in a north and south direction, and therefore athwart the storm track, the storm is held back by the height, it must follow valleys to the north and to the south until it can find a gentle slope over which it may pass on its eastward course, but shorn of much of its power by the attempt to overcome the restraining conditions.

The two continental "highs" indicated by this writer are placed in March, one over the valleys of the Missouri and Red River (north) northwardly to Manitoba, and the other on the Pacific coast, from about Cape Mendocino southward. The two "lows" are found, one resting on the extreme northwestern coast, the other drawn upon the southern part of the Great Basin, covering most of Nevada and Utah and considerable adjacent areas of Arizona, New Mexico, and the western slopes of Colorado. In April the Missouri high is outlined upon the whole central valley. The Pacific one is strongly accentuated on the coast line. The lows are to the north broadly outlined upon Montana and adjacent British America; to the south it is restricted narrowly to the lower section of the Great Basin and down the Colorado Valley.

Once assumed, these remain "fairly permanent for several months;" for even when some transient barometric disturbances occur, conditions are rapidly resumed. "The harmonic vibrations are confined to the swinging in and out" at the east and north, under the influence of "the eastern high." In May, this has moved over the Appalachian heights. In June, it swings back upon the central valley and the accompanying low "is found across Montana, North Dakota, and Minnesota." The July movement carries the "high" still farther east, resting upon the south Appalachian range and their regional coast line of Atlantic and Gulf. Again in August it is carried back into the lower central valley and loses its type character. At this time the North Pacific "high" begins to encroach upon the land. The eastern pendulum has ceased its movement. That now spreads out along the whole Atlantic coast. The northern "low" is again seen over Manitoba. The southern appears to be restricted to the Colorado Valley. The Pacific "high" in September is seen to overlie Washington and Oregon, with adjacent portions of California and Idaho. There is little change in October, except a "drawing together of the two highs." The low remains for September and October—north over Manitoba, south over the lower Colorado. The Pacific "high" is further inland and the eastern is drawn over the whole Mississippi Valley. The four forces are again in "expectant" poise. November discloses the waiting movement. "The climatic constants have been moved in longitude; they are eastward by 20 degrees of arc. Upon the Pacific coast the "high," which began to creep upon the land in August by almost imperceptible movements, now rests upon the Great Basin, and extends over southern Idaho and northwestern Colorado. The "concomitant lows appear north and south upon the Pacific coast, on western Washington and northwest Oregon, and on southern California, respectively."

Thus far has been seen a season of typical movement followed by a brief transitional rest, to be succeeded by a second type equally cosmical and permanent. November conditions endure to January; the "high persists upon the Great Basin; the low on the Pacific remains permanent in western Washington; the second low on the Pacific has a progressive eastward motion of slow rate." The February change is only in the Pacific southern "low," which has definitely moved eastward to the Colorado Valley. March rounds out the year. The "low" just named has moved over the southern section of the Great Basin. The eastern "high," which has been quiescent, moves west as far as the Missouri Valley, and the high that has rested over the Great Basin recurs to the Pacific coast. It is these recurrent operations that condition the whole climatic phenomena. The summers upon the Pacific coast and the Great Valley are alike defined by the two high barometrical areas. The Pacific winter is defined by a "high," in the Great Basin, and two "lows" upon the coast prevailing from November to March, a period of five months. The summer type is that of most persistent drought, the two transition periods, September and October and March, are mixed, rainy or dry, according to conditions just preceding, and the winter type is that of the greatest rain fall.

The economic effects of these conditions are of the utmost importance to both ordinary and irrigation agriculturist. With the flow of mountain streams and river valleys in the region of Cordilleran topography the hydraulic inquirer is most directly concerned. So also with the practicability of storage of storm waters, or their recovery as phreatic and artesian flows. The broad factors indicated in the preceeding summary of the most important and comprehensive review of our permanent continental climatic conditions yet prepared, are three: The pelagic or ocean currents, bearing a vast aqueous flow to the Pacific coast; the great mountain formations against which these aqueous currents precipitate themselves, and finally, the barometric conditions that permanently arise and recur as a result of altitude and latitude, making seasonal distinction and producing dynamic forces which inincrease or decrease the effects produced by the static conditions of mountain planes and elevations. Certain broad and economic outlines are naturally projected by such a sweeping study. They can only be indicated at this place as guiding points for further inquiry. The precipitation which falls upon the earth is either carried off and down by surface channels which have been eroded through preceeding currents or it leaks into the earth itself, to reappear below as springs, and rise when tapped as artesian flows, or to come again to the surface when intervening stratum are opened or removed so that by gravity or lifting by mechanical means there may be assumed and obtained a restoration of rainfall that has been stored phreatically as it fell from clouds to earth surfaces. Of the precipitation, then, there is loss by sinkage, seepage, and imbibition, or by evaporation. The latter is without recovery; the other may, as indicated, be restored to the uses of man, at least to a large degree.

Evaporation in California, as elsewhere, is a matter of importance in examining the availability of precipitation for purposes of reclamation and cultivation. The provisional curves constructed from the observations already made indicate the neighborhood of Owens Lake, Ingo County, as showing the maximum curve of loss; that is, 100 inches. The 90-inch curve enters the State as a narrow loop at Yuma and is drawn along the eastern base of the Sierra Nevada until it recurves southeastward just above Owens Lake, and reënters Arizona across the Nevada plateau at Mojave. The 80-inch curve follows very closely the preceding one, projecting northward in Nevada as far as Winnemucca. The 70-inch curve follows the southeast mountain flanks and the southeast deserts of Nevada, and at Lake Tahoe swings northeasterly into eastern Oregon. The 60-inch and 70-inch curves belong to the great valley and are drawn upon the southern coast range along its extreme length till it passes north. The 40-inch curve follows and parallels the range and coast lines.

These factors bring the discussion to direct consideration of climate and weather. The two controlling superficial factors of ocean winds and massive mountain barriers give for California and Nevada "a climate which differs from that of any district within this country and which, practically constant as a whole, displays equally constant differences between the several natural districts into which the region is divided." There is also to be considered the fact that as a whole the region has its own distinctive climate, which is thus described by Mr. Glassford:

> The distinguishing characteristic of the climate of the region is that varieties of weather endure practically unaltered for days at a time, and even when supplanted by others return again and again, and on each such recurrence are symmetrical with their

former appearance, even when they are not practically identical. In this regard there is a wide variation from the conditions which obtain elsewhere in the United States. Nor is this the only difference. Another notable one is that the storms of the Pacific are with comparative infrequnency traced across into the Central Valley and the Atlantic slopes. Another is that storm frequency increases rapidly towards the north.

The storms referred to are seldom felt below Cape Mendicino on the coast, while bringing rain to the San Joaquin Valley and as far south as San Luis Obispo. The southern part is untouched except by a "low" sometimes briefly developed in Sonora, New Mexico. Light showers occur from San Francisco northward, when there is a low shallow area over the North Pacific in the latitude of and not far from Washington. This rain seldom passes south of San Francisco. Low pressure then over Oregon and Washington results in rains over northern California when however a high area rests upon the two northern States. Quoting Mr. Glassford, we find that:

> The low type is permanent over Southern California. * * * A diffused and moderate "high" on the southwest coast is accompanied by an unusually low temperature. During this condition rains fall in the Los Angeles region and southern portions of the great valley. A considerable general fall occurs with a retaining "high" barometer on the southwest coast and heavy gales, hail and thunder storms may result. Local rainfalls are marked by a moderate "low" continued for several days and below the normal "over a large area."

Mr. Glassford continues:

> The dry season shows little variation from beginning to end. Rain is almost entirely absent and the light showers which sometimes occur on the Washington coast only rarely drop down upon a limited district of the California coast. Another feature of the season is the development and persistence of marked intensity of the "high" in Oregon accompanied with a corresponding fixity of a slight low area over southern California, creating the characteristic northerly winds which blow down the great valley.

A study of the rain curves shown in California as well as Nevada is one of great interest. Mr. Glassford puts the line of arid demarcation at 20 inches of annual precipitation, an estimate which this office accepts as reasonable. The whole of Nevada below its Sierra summits is within the Great Basin region and below the 20-inch curve. It is affected by a 5-inch curve which crosses the Mojave Desert and extends over the 3,000-foot plateau of western Nevada as far east as to include the Carson and Humboldt lakes. This curve in a narrow belt also crosses northeast Nevada and penetrates Utah to the extreme northwest of Salt Lake. A 10-inch curve peculiar to the Great Basin enters from the east, between latitude 37 and 38 and moves westerly across Nevada to a point beyond Pyramid Lake, where it turns southwest and moves until it is lost under the influence of the Colorado Desert dessication. I quote:

> In eastern Nevada a narrow loop of 15 inches clings to the north and south valleys of the White Pine ranges from Pioche to Fort Halleck. The general 15-inch curve of the Great Basin enters upon the northern border at Fort McDermitt, sweeps eastward to include Tuscarora, and then swinging sharply back along the upper edge of the basin parallels the 10-inch curve of the same system upon the eastern Sierra face as far as the heights which break away above the Tehachpi Pass.

It then descends the Sierra slopes and enters the great valley to be lost on its lower plane. The lowest rain curve (3-inch) in California enters at Yuma and controls the Colorado Desert. The 5-inch curve follows the river on its eastern edge, passing northward to the Mojave Desert, reentering it at Daggett and curving southward again to the river at the Needles; thence it enters Nevada as already stated, extending northeast to the Humboldt.

The 10-inch curve and less appears in the lower portion of the San

Joaquin Valley, again along the San Diego coast, the Upper Santa Ana Valley, and at the junction of the San Joaquin and Sacramento rivers. The 15-inch curve which enters from the Great Basin rises along the heights which break away to the east of the Tehachepe range, in southern California, enters the great valley, and at once seeks the lower contours, coming out into the level plains at Fresno. To the north it marks the controlling influence of Merced, Stanislaus, and San Joaquin counties, going north to the slough region of Sacramento, Solano, and Contra Costa counties, and then climbs slowly south and to the west of Lake Tulare, where it marks the line of dry currents from the San Joaquin Valley and the desiccated one from the Colorado Desert. The 15-inch curve is marked also upon the eastern slope of the Coast Range, along the 1,000-foot contour of the Santa Ana, and sweeps around the 10-inch curve. It is also seen in Salinas Valley and San Benito County, as well as in the Sacramento Valley, Colusa County. The 25-inch curve enters from Oregon about the center of the northern boundary and moves east and southeast to Sisikiyou, Shasta, Plumas, and Lassen counties and beyond as far as the head of Kern River. Returning north it follows the foothills, seeking and modifying the lower level curves, until Red Bluff in the north is reached; thence it recurves, taking the Sacramento Valley southward, round the Sonoma Valley, and into the Bay of San Francisco. The neighborhoods of Ukiah and the Upper Russian River are under its influence also. It runs southward along the Coast Range heights, reaching Mount Julian, where the rise is upward to 35 inches. From there the general curve of 25 moves across Ventura County. It affects the coast from San Benito to Mount Hamilton, has a place on the southern portion of the San Francisco peninsula, and over portions of the bay region in Contra Costa and Alameda counties. The 30-inch curve follows, but above, the general direction along the higher Sierra of the preceding one. Its southward limit is the head of Kings River, where it turns north, along a lower alignment being drawn into the Sacramento Valley as it moves north. At Shasta it recurves and moves along the inner slopes of the Coast Range southward to San Pablo Bay, passing out to sea at Mount Tamalpais. All of the remaining curves are confined as to influence to northern California. The 35-inch is mainly confined to the vicinity of Redding. Higher curves follow alignments, showing higher latitude and low altitude, thus proving their entire dependence for regulation upon the ocean currents of the north Pacific, as already mentioned in this summary. The 40-inch and the 45-inch curves are found aligned along the headwaters of the Tuolumne and Stanislaus rivers, passing westward up the Trinity and through Round Valley, leaving the land south of Cape Mendocino. The rapid increase at certain seasons in the flow of the rivers named is due to the large precipitation shown. This is a matter of grave importance, as it insures the permanence of great irrigation supply which has hardly been drawn upon. The water storage of the important Turlock and Modesto districts is directly related, it will be seen, to the 40-inch and 45-inch curves, which, as precipitation in either rain or snow, feed the notable mountain river at whose debouching cañon mouth the storage dams of the two districts named are now in process of construction. The irrigation districts in Colusa County are also endowed with secure sources of supply. It is quite a reasonable estimate, then, to regard the mountain streams of central and northern California as capable of furnishing water sufficient to irrigate four or five times the number of acres now under such cultivation in the Golden State.

California presents the oldest as well as the best example of farming by irrigation within the United States, as it does the most fascinating of physical conditions. The Franciscan Fathers partially systematized irrigation a century ago, and when their semi-municipal control of the Indians was absorbed by the Mexican Government, followed as it was by the American conquest, the art (relegated to the care of the Indians and Mexican land grantees), was practically ignored.

During the American settlement incident to the gold excitement agriculture had little place. The necessity of a permanent food supply for the growing population was soon brought to the front, however. But the wide-stretching acres of the great wheat ranches alone yielded profit, and there were many reasons for this, because, while production was limited to staples giving small returns, $1 an acre with an indifferent culture on a 10,000 or 20,000 acre ranch represented a greater profit than $5 or $10 per acre to the small but careful farmer. An early report of the State Agricultural Society says:

> We have within the geographical limits of California over 100,000,000 acres of land, of which less than one two-hundredth part is under cultivation.

A system of crop culture that afforded the product of only 500,000 acres of poorly tilled land (1862) for the support of more than that number of persons could not stand.

According to Engineer William Ham Hall, in 1852 a band of Mormons from Salt Lake took possession in San Bernardino of some old mission works, bought a Mexican rancho there and commenced irrigation, which was probably the first noteworthy effort made by other than Mexicans; in 1856 some Missourians diverted water from the Kern River in that county; in 1858 the water of the Cache Creek in the Sacramento Valley was taken out, and in 1859 a little water for irrigation was developed from Kern River. With so little of the arable lands irrigated and such large tracts sowed to broadcast crops, the introduction of a system whose very essence is intensive cultivation was a difficult and disheartening process. The employment of unskilled labor on an irrigated tract counts the loss of from 30 to 50 per cent of the crop. The land requires constant care and the crops the utmost watchfulness. In an irrigated region the small farm seems to be a logical sequence of the system. Besides this, under Spanish-Mexican law, water for irrigation is held to be subject to beneficial servitudes, or it might be expressed "to run with the land." The mining settlement gave shape to the agricultural control of water for cultivation, and prior appropriation was the rule almost wholly among those who farmed and made homes. The stockmen, the sheep rancher, and the speculative landowners were commonly advocates, on the other hand, of riparian rights. This did not become a marked issue until irrigation and colony life grew into a vigorous economic factor. But the whole plan of prior appropriation, though generally supported by the court, was a shiftless affair. No rule for its government was laid down; no supervision was provided for or enforced. The legal requirements were simply that the claimant of water for irrigation should post a notice of appropriation at the point of diversion and within sixty days thereafter begin the construction of his works. Usually a copy of the claim was filed at the county seat, but no State or municipal inspection or measurement was provided, nor were the records properly preserved. The claims were generally couched in very indefinite terms, being worded by the farmers and corporations immediately interested. The development under this loose administration and acquisition of water rights was very slow, capital was wary, and the peculiar feature of this indefinite period, down to the adoption of the irrigation district system is, that progress was greatest in those regions presenting greatest natural obstacles, as in the difficult southern counties rather than in more favored basin plains, owing to the greater security of absolute proof of prior appropriation and beneficial use. In early irrigation the object was to get water to particular tracts owned by the appropriator, and not to put it on the most available land, which in most instances was more convenient to the head gate of the canal.

For example, in the San Joaquin Valley four large canals now pass within 2 miles of Centerville, in Fresno County, at equal elevation and commanding the same territory, the waters of which are directed to unrelated tracts of land. One canal of greater capacity than all four combined would command a larger and more compact territory at much less cost. In 1870, the real development of the water resources of California began. The Commission authorized by Congress, under a resolution of Senator Stewart, of Nevada, in 1868-'69, to investigate the San Joaquin Valley, endeavored to prove that there was a permanent and sufficient water supply to be found there for the irrigation of large areas. That report, as well as actual cultivation, showed that the rich soil of valley and plains were among the best lands in the world for extensive and diversified agriculture. Under a notice claiming "right to construct a ditch 10 feet wide, 1½ foot deep, or to a volume of water of 2,160 inches," posted July 5, 1865, the Centerville Canal and Irrigation Company, in 1868 and 1869, built an irrigation canal, using Centerville slough, one of the channels of King River, thence south and west to Burns Slough, another natural channel, which was utilized, and thence to the lands served in the vicinity of Centerville, on August 5, 1869. The water right of this ditch was enlarged under a location of J. B. Sween, "from the margin of said river (King's) 10 feet wide at bottom and 2 feet deep under a 4-inch pressure." In 1870, M. J. Church and A. Y. Easterby entered upon the Fresno Canal and Irrigation Company's project to appropriate at the head of Sweens Ditch, "water to be taken from King River at the upper end of Sweens Ditch, 20 feet at bottom and 30 feet on top, and 4 feet deep." In 1874, this company acquired all the rights of the Centerville and Sween Canals. The Fresno Canal and Irrigation Company was the first illustration of irrigation on a large scale in the United States, being a short period in advance of the famous irrigation colony at Greeley, Colo. Many vicissitudes marked its early history. Messrs. Church & Easterby becoming involved in financial difficulties the canal passed under control of the Nevada Bank, but it failed to pay dividends and after a time was sold back to Mr. Church, and since then has remained under the management of the company of which he is president. When the waters of this canal were first poured over the land the soil was powdery and dry to a depth of 50 to 90 feet, and absorbed water like a sponge. In order to get the water to run a full head was allowed to flow into the ditch for a short distance; it was then shut off and permitted to settle and deposit its load of silt. The bed of the canal would thus present a smooth, glassy appearance, and before the film of sediment cracked in the sun a new flood was let down to the next dry section. The sediment thus formed had the tendency to puddle the bed of the canal.

Before noticing more fully the irrigation in this region, a glance at the topography will help to better understand the subsequent development. The San Joaquin Valley is a vast intramountain plain, extending north from the Tehachepe Range to the junction of the Sacramento and San Joaquin rivers, and east and west is walled in by the Sierra Nevada and coast ranges. The San Joaquin River carries off its drainage. It comes out of Sierra midway in the valley, picking up at Las Juntas the surface flow from Kern, Tule, Keweah, and King rivers. All head in the eastern range and debouch on the plains, resembling the skeletons of four leaves laid side by side, the stems in each case being the main or cañon stream and the delta being the frame of the leaf. In the southern end of the valley enormous precipitation is poured down from the Sierra without forming a permanent water way. Tulare, Buena Vista, Kern, and Goose lakes are the only evidences of this vast flow, but even they have no constant outlet towards the San Joaquin River, other than a series of swamps and tule beds. The soil before irrigation was dry below the reach of suction pumps. The eastern side of the valley is well watered, but on the western or coast range side there is scarcely a stream perennially flowing into the San Joaquin Basin; certainly not a single one below the junction of that river and the Merced. The irrigation has naturally been on the eastern side of the valley. Some effort is now being made on the western side. Twenty-five years ago the San Joaquin Valley was only known as a dreary stage in the journey to the mines of the Sierra Nevada mountains. Bakersfield, Visalia, Fresno, and Merced were simply hamlets. The canals that have filled the land with plenty were only dreams of students and visionaries. The stockmen held supreme control over the foothills and plains, and their opposition to irrigation was violent.

The success which followed the introduction of irrigation into the San Joaquin Valley stimulated exertion elsewhere, and the practice was improved on in the six southern counties, which latter, owing to the large profits on their products, have become the best-known irrigated region in the United States. The open canals have been often described, and that need not be reiterated. It is necessary, however, to dwell briefly upon one peculiar feature of irrigation in the San Joaquin Valley, viz, the lifting of the water table, or plane, towards the surface. In this region the canals are all constructed for the avowed purpose of allowing seepage into the soil through their banks. The result is that lands on which from $5 to $20 per acre have been paid for the right to use water are now filled to saturation. Drainage is often needed to carry off the constantly increasing soil water. As yet this destruction of the land has not been very general, but it must be reckoned on within the near future. The only danger is that the land may degenerate into a swamp. Engineer Wm. Ham. Hall, in a paper read before the American Society of Civil Engineers, says:

> I saw in 1877 enough water, by actual measurement of flow, put on 20 acres of land to cover it 18 feet deep, in one season, could it all have been retained upon it. It simply soaked into the ground or flowed out under the great plain. Taking cross sections of this country, north and south, east and west, I found that where the depth to soil water had, before irrigation, been about 80 feet, it was then 20, 30, 40, or 60 and more feet down to it. The soil water stood under the plain in the form of a mountain, the slope running down 40 to 50 feet in a few miles on the west and north. On the south and southwest the surface of this water mountain was much more steep. In the Kern River country we have a somewhat similar phenomenon. Irrigation, in the upper portion of the Kern delta, affects the water in the wells 6 or 8 miles away. As I remember, the effect is felt at the rate of about a mile a day; that is to say, when water is used in irrigating the upper portion of the delta, or of Kern Island, as it is called, the wells commence to rise a mile away in twenty-four hours, and five miles away in perhaps five days.

It is claimed that the more water in the soil the better it is for the irrigator, as it is not only preserved without loss by evaporation, but tends to more constantly feed the rivers, whose flow during the dry season has greatly increased since the introduction of irrigation. Mr. J. P. Vincent, of Fresno, Cal., speaking to the special agent on this point, said:

> The fruit area of Fresno County is increasing, and will continue until all available lands are put under cultivation. In the early days we said we had 7,000 acres of irrigable land, and outside of that nothing; but now we have 7,000 acres that are drained in order to raise crops. For the old vines we use very little water, but for the new ones we use very large quantities, as the desire is to saturate our lands. The vineyards are extending principally towards the foothills. Wherever we put water we plant crops, but we are extending towards the foothills, because the soil is heavier and freer from alkali. The best part of our wheat is raised in that direction. If we used our water at the proper time we could irrigate even more land than we now do. Our supply is sufficient for all purposes, and we have not yet considered the question of storage. In winter we can flood our land 4 feet deep, and thereby save irrigation in the low-water season of summer. Our object is to fill the land, and instead of having it 60 feet below surface, we want the water plane to be from 6 to 8 feet only. In the vicinity of Fresno, northeast to the Enterprise Colony, the water plane has risen to within 30 feet of the surface. In some places it is less. Along the lines of the canals there has beeh without exception a general rise. This has enabled us to extend constantly the area of planting from a surface supply, originally considered very inadequate. There has been quite an extensive increase in the planting of vines and trees during the winter and spring of 1890-'91.

J. C. Shepard also described the method of using seepage water for subirrigation.

> The duty of water is now supposed to be 1 cubic foot per second to 160 acres of land, but if you take into account the amount of land planted to vineyards and orchards, not watered at all on the surface, but made fruitful through seepage subirrigation, it will be somewhat more. These lands receive their water, by percolation, from the ditches under which they lie. There is an impression that we run a ditch around a thousand acres or so and allow it to seep up, but this is not so. We run the water right on the land wherever we irrigate at all; the nonirrigated only receives moisture from the seepage of the wet lands or from the ditches. The greater part of the country east of Fresno, between here and Kings River, where vineyards have been planted, is not irrigated at all. Some of these vineyards have never been irrigated, and there are no ditches on them. The only water they get besides rainfall is through the seepage of the main ditch. The country falls to the south and west, and the surface water has risen from a depth below the reach of suction pumps near enough now to the surface to supply the roots plant. The effect of this seepage is very noticeable, because the country is full of depressions, which have filled with water and are covered with tules. This is seen for a distance of 25 miles or more south and west from Fresno. Farming in this region is now carried on under much more favorable conditions than when our colony life began. Water for stock is more easily obtained, and while the ground water has not risen high enough for grain, still many crops are greatly benefited, among which is alfalfa. It grows in many instances without surface watering.

The following tables of water loss from canals were made by Mr. C. E. Grunsky, ex-assistant State engineer of California, during his official investigation of the region under consideration. These tables, with other valuable material in part incorporated in this report, have been received from Mr. Grunsky for use by the office of irrigation inquiry. The abolition of the State engineer's office has prevented the further prosecution of these important observations:

Loss of water from the Kings River and Fresno Canal.

[Measurements by C. E. Grunsky, assistant State engineer.]

Name of canal or ditch and locality.	Distance below head of canal.	Discharge (cu. ft per sec.).		Loss between stations (cu. ft. per sec.).	
		Main canal.	Diverted.	Total.	Per mile.
	Miles.				
K. R. & F. C., one-half mile below head	0.50	133.83	....	43.36	3.77
Burns Ditch	1.00	....	0.25		
Hansen Ditch	4.00	....	3.23		
Fanshaw Creek (wastage)	8.00	....	0.30		
Ditch on south side	8.00	....	4.05		
Ditch on south side	9.00	....	0.05		
K. R. & F. C. at Hawkins Weir	9.00	*78.18	....		
Wastage	....	....	0.15		
Ditch on south side	11.50	....	2.04		
K. C. & F. C. in Red Bank Creek flume	12.00	80.40	....	16.50	3.48
Dog Creek (wastage)	13.25	....	0.15		
Ditch on north side	16.00	....	3.36		
Eggers Ditch	16.75	....	4.67		
K. R. & F. C. at Eggers Weir	16.75	55.72	....		
K. R. & F. C. west line of section 17	17.75	*49.56	....	4.44	1.25
Ditch south side	17.80	....	3.08		
Scand. Col. Ditch	18.25	....	3.86		
K. R. & F. C. at upper Scand. Col. Weir	18.25	*36.74	....		
Scand. Col. Ditch	18.35	....	1.46		
Scand. Col. Ditch	18.50	....	2.42		
Scand. Col. Ditch	18.60	....	1.00		
Scand. Col. Ditch	18.70	....	2.39		
Scand. Col. Ditch	18.80	....	14.50		
K. R. & F. C., Lower Scand. Col. Weir	19.00	*21.51	....		
Big Creek (wastage)	19.25	....	1.50		
Wastage	....	....	0.20		
Ditch on north side	19.75	....	0.43		
Cooper & Helm Ditch	20.25	....	8.71		
K. R. & F. C. at Cooper Weir	20.30	11.73	....		

*Approximate.

Loss of water from the Fresno Canal.

Name of canal or ditch and locality.	Distance below head of canal.	Discharge (cu. ft. per sec.).		Loss between stations (cu. ft. per sec.).	
		Main canal.	Diverted.	Total.	Per mile.
	Miles.				
Fresco Canal at Road Bridge	1.25	381.00	....	95.51	8.49
Centerville Branch	1.75	....	17.80		
Lone Tree Branch	3.25	....	60.39		
Ditch on south side	5.00	....	0.50		
Limbaugh Dam Ditch	12.50	....	58.72		
Fresno Canal at Limbaugh Dam	12.50	139.08	....	5.20	0.74
Briggs Canal	14.00	....	0.30		
Eisen Canal	14.00	....	14.09		
Fresno Canal at Hobler Dam	14.00	*107.58	....		
Easterly Ditch	17.25	....	5.60		
Malters Ditch (North)	19.00	....	6.30		
Malters Ditch (Central)	19.00	....	1.69		
Washington Col. Branch	19.50	....	45.50		
Fresno Canal at head of Wash. Col. Branch	19.50	60.40	....	3.81	0.95
Fresno Colony Canal	23.50	....	14.15		
North Central Col. Canal	23.50	28.16	13.88		
Main Central Col. Canal	23.50	28.16	....		

*Approximate.

Loss of water from the Centerville and Kingsburg Canal.

Name of canal or ditch, and location.	Distance below head of canal.	Discharge, cu. ft. per. sec.		Loss between stations.	
		Main canal.	Diverted.	Total.	Per mile.
	Miles.				
C. & K. canal, ½ mile below head	0.50	346.00	....		
Ditch on west side	5.50		5.06	85.94	15.63
Do	5.75	....	4.00		
C. & K. Canal at Wier, in sec. 23	6.00	251.00	....		
Garfield Canal	7.00	....	26.65	52.35	52.35
C. & K. Canal at Wier, in sec. 26	7.00	172.00	....		

The loss by evaporation on the Fresno Canal, throughout its 24½ miles of main canal, as arrived at by the same authority, from observations extending from 1881 to 1885, was equal to a continuous flow from the ditch of 2.8 cubic feet per second for the total length.

The humus or vegetable mold of which the soil of the southern end of the San Joaquin Valley is composed, in connection with its arid climate, has a tendency to "bloom" out in alkali, a prevalent form being what is known as black alkali. Underdrainage, however, is the natural corrective of alkali eruptions on the soil, and a local system of irrigation drainage must therefore be adopted. It is certain that with care the alkali will quickly cease to be a source of uneasiness. Irrigation must in the very nature of the art be the result of associated effort. The first large canal, as already described, was taken out by a private corporation, and the water contracts of this company, with its irrigators, called for a pro rata share of the water in the ditch. This clause was soon taken advantage of for the formation of colonies, by which a body of persons desirous of enjoying the advantages of associated effort organized for mutual assistance in the building of ditches, etc. The locations these bodies made are among the most prosperous in California.

As an illustration, in the San Joaquin Valley land values have advanced from less than $5 per acre for land without water to $200 and $250 for land with water. In southern California and all the citrus regions the price of watered land is double that of San Joaquin areas. Speculation in land and water rights aimed till recently to make the latter a personal franchise rather than an easement of the land. The right of prior appropriation was pushed to the uttermost, and in the conflict that ensued from 1870 to 1885 the courts were burdened with the suits of water-users, water-owners, and those between rival companies of owners. Such was the state of affairs at the time of the introduction and passage of the first Wright irrigation district law. The several laws, so known, are an effort to give the highest legal sanction to the permanent union of the land and water, but at the same time to recognize every other existing right and equity. The question with the people interested was the method of union. It was common sentiment that some such course was necessary, but the ways and means were the vital question. At an interview between the special agent in charge and Mr. C. C. Wright, the author of the present district laws, and Mr. Nance, the president of the California State Association of Irrigation Districts, Mr. Wright expressed himself as follows:

> I was elected to the legislature for the express purpose of advocating some measure providing for the municipal control of water for irrigation. In devising plans it occurred to me that the best method whereby the people could organize, and when organized would have power to assess and collect money for the purpose of construct-

ing works by the ordinary process of levy and collection, was the proper thing, and that a local government based on the familiar lines of county government and officers, differing in no respect from such an organization, except in the object to be attained, would accomplish our purpose without chance of failure. So, this district law was formed with the object in view that there might be created a special government for the one purpose of developing and administering the irrigation water for the benefit of the people. The idea was to organize a local government for this purpose and the single object of providing works and paying for their construction; and it seemed to me best to adopt a somewhat more limited municipal organization than that of the counties, or a municipal organization for one purpose only. There was nothing new or novel in that plan. The district when effected is the same as a county. It has its board of directors as the county has, its board of supervisors, and assessor, treasurer, and all other officers necessary, within its municipality, whose duties within the district correspond to the duties of similar officers in counties. The proper county officials are empowered to provide for the construction of any needed work, such as a jail, court-house, bridge, road, etc., and to do it by direct assessment; but if the cost is too great for that method, by an issue of properly authorized bonds. It is just the same with an irrigation district. The board of directors were given the same general power to construct a system of irrigation works as is given to a county.

Then, as to the method of community association or election in a district, I thought again that the mode of forming municipal bodies in this State should be followed. The legislature can select a municipality or district by direct act, but there must first be a petition from a certain number of freeholders; and then there should be an examination by a board of supervisors, who could employ engineers, etc., to report upon the formation of the district, and they should have every facility afforded them to make a thorough and exhaustive examination into the propriety of forming the district. When satisfied as to this they should be authorized to fix the boundaries and propose to the people whether the district should be so organized; and after such a proposition has been made with sufficient notice, if the vote of the people showed two-thirds in favor of forming the district, then that vote should operate as the act or fact which should result in the formation of the said district.

First. The formation is provided for the same as other corporations in the State.

Second. When the district is formed the plan is to be carried out on the lines similar to those upon which county government is laid down.

Third. The plan for raising money is the same as that of a county. The board of supervisors make assessments to construct a work, and, just so, the directors make an assessment and submit it to a vote of the people for an irrigation ditch or reservoir; they make specifications and advertise for bids under the system of competitive bidding, and award the work to the lowest bidder.

Another thing is that if the district should be compelled to issue bonds when the amount needed be too large for direct assessments, a proposition to vote bonds may be submitted; if that prove insufficient another proposition may be submitted and a second issue voted, but the directors are empowered by law to levy a direct assessment and complete the work. This power is granted in order that the work may not be commenced and then allowed to remain unfinished.

As to the obstacles to setting these districts on their feet, the only important one has been the lack of confidence in the bonds. They are a new security. Everybody acknowledges that the decisions of the Supreme Court have set at rest all legal questions involved; but yet it has not done away with the feeling that these are new and unproved securities. Capitalists are slow to take them. There has been some opposition of a pronounced character from the large land-owners who have a notion that they owned not only the land, but the water and the people also, and they will antagonize any attempt on the part of the people whereby they may become entitled to any part of the water. The large land-owners want the water themselves, and they do not want cultivated lands brought in competition with their own. As to the question of taxing lands because their value is increased by the irrigating ditches, I think that is best handled by our system of assessment and equalization, which is the same as the county plan, and I have studied that plan a great deal. There is nothing in the law to prevent all lands being assessed at the same figure. It might all be assessed at $50, for in such cases the land is supposed to be intrinsically of the same value. Then the board of directors, sitting as a board of equalization, will finally settle the question, and poorer land be assessed at its proper value. If, on the other hand, you make a cast-iron rule that the poor acre would have to pay as much as the good acre, it would be wrong, but the equalization makes that all right. There is no reason why the system should fail because the assessments are equal; and experience has shown that there is no reason why a district may not carry on a complex system of irrigation. The canals and their administration is as natural to the district as the building and management of highways is to the country.

As to the public or government lands within the district area, I think it would be the proper thing for Congress to pass an act making them liable for cost of district works. The holder of such lands must take them subject to a lien for the improvements. I know that there are many people who have delayed taking out their patents in order to escape paying water assessments. As it is, we have gone ahead and entered the assessments, and when the owner of such lands wants water for them he will have to make some equitable arrangement in regard to the expense of the works and other details. On the mere basis of benefit to the public lands Congress ought to authorize a thorough investigation into the district system, the feasibility of its operation, source of supply, character of soils, and character of security it offers for investments. This would serve to promote irrigation interests all over the country.

Mr. Nance declared that:

The great effect of the district system will be to lessen the cost of water to the user at least one-half. In the Alta district of Fresno and Tulare counties the expense of furnishing water, including interest on the entire debt of $410,000, will not exceed 25 cents per acre for the past year. [Mr. C. C. Wright has more recently stated at 40 cents.] Under the old system it was $5 per acre royalty or franchise and $1 per annum for rental. It had been as low as 50 cents, but it was raised to $1. There are no royalties or franchises under the district system. The only cost during the first ten years of the existence of the district is that of interest on bonds, maintenance, and administration. You do not begin the formation of a sinking fund for the payment of the principal of the bonds until after ten years. After ten years you begin to pay back the principal. You might consider it in this way: In the Alta district the amount of money to be expended during the whole period of twenty years, including interest and principal of bonds, is $5.19 per acre. If you consider that as a royalty you will get at the cost of a district system to the irrigators, with the exception that you do not have to pay the royalty in a lump sum, but spread out over a period of twenty years, during which time your land has been yielding a return, and after the bonded debt is wiped out the expense of running will only be 7 or 8 cents per acre.

Mr. J. C. Shepard, of Fresno, in speaking of the district system, said:

The Wright law is a long step toward the proper method of irrigation. It may not be perfect, but it will be very hard to get a law that would be better. Under it the people, or rather the water users, become the owners and controllers of the water, the works, and the administration thereof, paying of course for such capital as they use in the construction of works, the title of water becomes finally vested in the title of the land. This system supersedes and does away with the litigation caused by the conflicting claims of riparian owners and prior appropriators, and the general impression is that it will work out well. As to the question of cost of the system, it is not thought that any man who compares the cost under the district system with that under a corporation will find the results unfavorable to the Wright law.

The large landowners have undoubtedly objected to the formation of irrigation districts because they would have to pay taxes on their land. This fact is apparent in the Alta district, where the large owner says the taxes are so heavy he can not afford to keep them up, and consequently he is seeking to dispose of the land in small parcels. It is either being sold out or the owner is letting people have it to plant on shares. Actual settlement and cultivation have increased the value of this land to $250 per acre. The large landowners have not paid a cent to bring about that increase, but under the district laws they would have to bear their equal share. Another obstacle besides the hostility of such landowners has been in cases like the Selma district, where there are three systems of canals, and it can not be agreed what is to be paid for them. This dispute has resulted in defeating the bond issue proposed. This hindrance has been caused by the ditch systems themselves. The law of course provides for the power of condemnation, but as yet we have not exercised it. I do not think this district will soon vote its bonds, because the directors of the canal companies want the directors of the district to make terms with them and to give a certain amount for their canals, which the district people refuse. Then the ditch owners started in to defeat the bonds and did it.

The general effect of the system when tried is to greatly lessen the cost of water to the irrigators, and when the districts are more unified the cost of administration will be much more reduced; besides this the intense public opinion and watchfulness aroused will be a check on the slightest unnecessary expense.

The views of Hon. J. P. Vincent, of Fresno, who was chairman of the committee on irrigation of the California assembly, during the discussion and passage of the first Wright law, are presented in this connection:

As to the application of the Wright system, I would state that it is much more difficult to apply it to a country like this where systems have grown up, than to a country where there is no irrigation at all. You see in this section, with our numerous systems and farmers under them, many of whom are stockholders in the canals, we are interested in the success of the present methods. If the present canals had only have been larger we could have irrigated much more land with less expense per acre. One of the great advantages of the Wright system is that it makes each man pay his share both of constructing and operating the canal. Now, in our experience we find that one man will not take and pay for water because his land is so situated that he will get his supply from his neighbor's seepage. We have a great many such men.

At the time the first Wright law was passed I was chairman of the irrigation committee of the California legislature. My idea was that we should form "water districts," which should own all the water of a stream irrespective of the construction of the canals. For instance, if a man owned 1,000 acres and there was only one-tenth enough water to irrigate it, he could only irrigate 100 acres. The idea was this, that every acre irrigable by King River, say, had a right to water. The result would be there would be about four times the amount of canal construction and there would be four or five times as much water taken out at the high stages and not so much needed at the low stage, and in that way the country would soon be filled with water and but little would be needed.

The greatest objection to the Wright law is that public works cost more than private works. Now, in the Tuolumne County, I think the Wright system is excellent, for unless some huge corporation should construct that Modesto and Turlock dam it would never be constructed. It is better therefore to have a district corporation for such a purpose than a private one. My idea was that every acre of land had its just right to water in a proportionate share. Then the people would construct canals, and even if the water was not sufficient to irrigate all the land it is better that way than that a few men shall have it all. I want every man to have some. More than that, when one man irrigates his land he benefits all his neighbors. If you will take a cross section of a ditch and the country under it you will see that the water seeps away until it strikes the next ditch, thereby benefiting every man under the canal, whether he pays for water or not.

Mr. Vincent was asked if the disposition of the vested rights, or the usages growing out of the present system of canals that have taken water in Fresno County, is the chief practical obstacle to the formation of districts under the Wright law in and around Fresno; were the people here satisfied and did not want to experiment any further?

In reply, Mr. Vincent said:

That is about the fact, but the idea I had was this: In sections where there are no canals established the Wright system is the best, because every man under it will pay his proportion of expense from the beginning and receive all the benefit. In sections such as Fresno where the people have rights under the canals, I think a water district would be better than an irrigation district—that is, all the land should be formed into a water district and then the people should purchase the vested rights now existing. The principal object of the Wright laws now seems to be the construction of irrigation works. In Fresno, for instance, it would not be necessary to construct irrigation works, because we have a system already; but if we could purchase all the water rights it would be better. I was not able to get my bill signed by the governor after it passed the legislature of 1887.

My idea was that the water in a water district should belong pro rata to the land irrigated. The tendency of such a system would be to make water common property. The man now who is nearest the head of the ditch can get more water than he needs, and if he don't buy it he gets it in various other ways. There is, in the opinion of many, but one honest man on each canal, and he is the last man that gets water. This system has been thought wasteful, but in this particular region we do not find so much fault with waste, as we want water to seep and fill the land.

After the passage of the irrigation district law Mr. Wright immediately interested himself in the formation of the Turlock district, which was the first formed under the law. The agitation of the question among the Turlock people led to the formation of the Modesto district. No better example of the flexibility of the system could be offered than these two districts. They are under separate management, but have united to build a great dam on the Tuolumne River, each bearing its proportionate share of expenses and adjusting all interests in the dam on a fair and equitable basis.

The following engineering review of the works was obtained by the special agent from Mr. C. E. Grunsky, C. E., during his investigation of Californian irrigation in 1891:

The Turlock irrigation district embraces within its boundaries 176,100 acres of the east side San Joaquin Valley plains. The district lies principally in Stanislaus County, only a small portion of it extending into Merced County. Tuolumne River forms its northern boundary and the Merced River lies at its southern limit. Its soils may be briefly described as sandy loams of great depth, excellent quality, and well adapted for irrigation. The rainfall throughout the district averages about 10 inches. The district in its present nonirrigated condition is a vast wheat field. By careful tillage the soil has been forced to yield cereals enough to be barely remunerative. Where water has been raised from wells by mills or horse power an occasional acre of orchard or vineyard emphasizes its productiveness. The surface of the ground is smooth and its slope quite uniform. Distributary canals throughout the district will therefore be located in most cases on land lines running from north to south or from east to west. The rivers between which the district lies have their sources in the high Sierra Nevada. The Merced River flows through the celebrated Yosemite Valley; the Tuolumne through the Hitch Hitchy. The former at Merced Falls, where it breaks from the mountain and enters upon its course across the east side plain of the San Joaquin Valley, lies in a secondary valley, being flanked by broad bottom lands from which bluffs rise 40 to 100 feet and more to the general surface of the east side plain of the main valley. The foothills of the Sierra Nevada gradually retreat from the river and have occasional spurs which protrude to the bluff overlooking the bottom lands.

Similar to the Merced River is the Tuolumne, but the projecting spurs of the foothills hug it more closely and follow it far out into the main valley. At Lagrange, just above which settlement the river breaks forth from a rock-bound narrow gorge or cañon, the area of the mountain drainage basin of this river is 1,480 square miles.

The elevation of the river at that point is about 200 feet above the ocean and that of the highest lands in the district, at a point about 13 miles further west, is about the same. Tuolumne River is the natural source of supply for this district; and that it will afford ample water is evident by the following table of flow in second feet, prepared in the office of the State engineer in 1885:

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1878	......	......	......	......	......	......	......	......	......	......	65	65
1879	478	1,876	2,797	4,456	5,086	7,061	1,977	183	39	30	101	903
1880	409	625	832	7,141	10,371	14,675	7,618	1,233	134	56	35	1,095
1881	2,884	6,755	2,879	6,260	7,274	5,225	1,996	391	125	130	193	620
1882	620	573	2,164	3,543	7,461	8,046	2,745	574	225	873	570	327
1883	654	490	1,310	3,270	8,180	6,540	1,635	490	327	262	327	327
1884	410	490	6,540	7,360	7,360	8,180	6,540	1,635	327	245	......	......

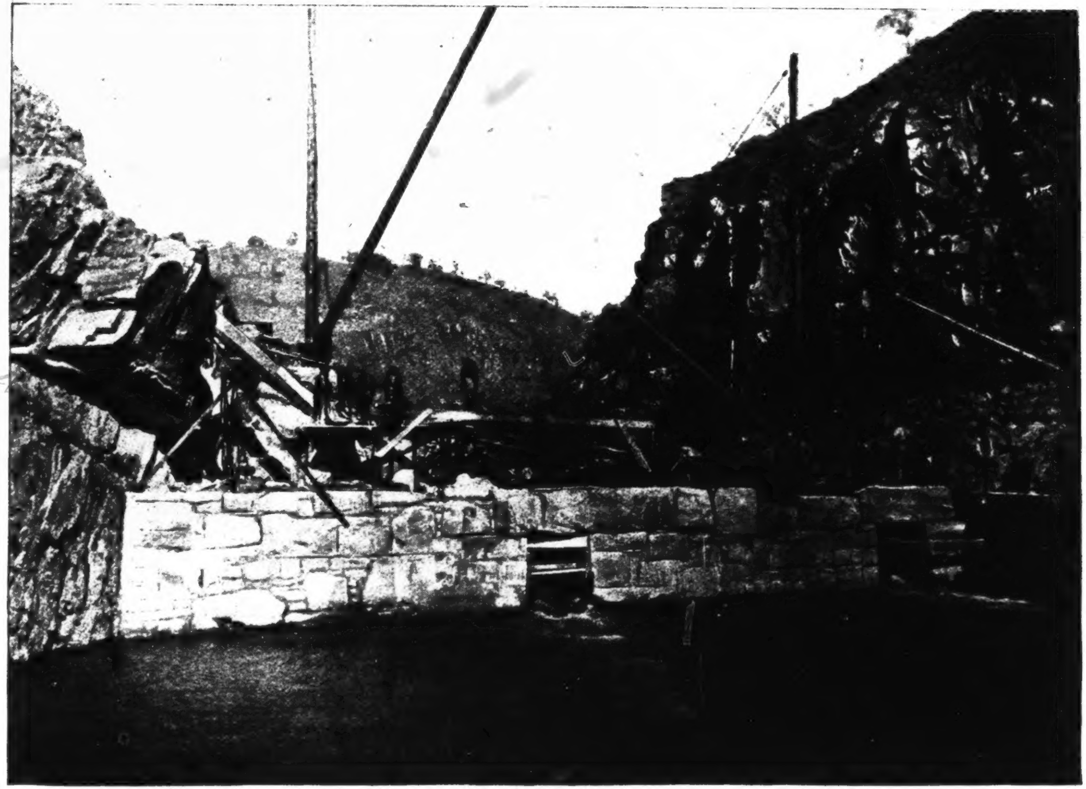
The capacity of the main canal as reported by the engineer of the district is 1,500 cubic feet per second. The duty of water (gross) expected of water in the district is 118 acres per second foot, on the basin of canal capacity. Although the lands to be irrigated are in part at least quite sandy, the duty of water is expected to be very low. A canal of somewhat smaller capacity would have been ample to supply the needs of the district; but a reduction in capacity would not have caused an equal reduction in cost of works, and as some one has said, the land owners in the district will be better satisfied with too much water than too little. Soon after its organization the district employed George Manuel as chief engineer, and on his estimate of probable cost the necessary issue of bonds was placed at $600,000. Little opposition to the scheme was manifested and the bonds were voted. After the necessary legal proceedings the laws under which the district was organized were decided to be constitutional by the supreme court of the State and the bond issue was then declared valid.

On specifications prepared by Engineer Manuel, the construction of works commenced in March, 1890, and was carried forward to the completion of about 18 miles of main canal excavation. Structures such as drops, flumes, and waste gates have not yet been constructed. The work inaugurated under Mr. Manuel's direction has been carried forward by his successor, E. H. Barton, the present district engineer. Original plans were improved upon as opportunity offered, and after long deliberations and many conferences with the Modesto district directors, which also looked to Tuolumne River as a source of supply, it was finally agreed by the board of directors of the two districts to construct a joint dam across the river at the mouth of its cañon, just above La Grange, on the "French Bar," immortalized by Bret Harte.

Plans from district engineers were called. It was agreed that the engineer whose plans were accepted should have charge of the construction. Subject to these terms the plans of Luther Wagoner were adopted, after having been pronounced the most acceptable by Col. G. H. Mendall, Engineer Corps, U. S. Army. Before the construction of the dam commenced Mr. Wagoner resigned as chief engineer of the Modesto district, and his plans for the dam are now being carried out under Mr. Barton's direction. The La Grange dam is constructed on the weir or overfall type. It will have a height of 105 feet, and extreme floods will sweep over its crest with a depth of about 16 feet. Its crest length will be 310 feet, the width of its crest 20 feet, the upstream face will be nearly vertical, the downstream face the shape of a pointed arch, each of the sides of which is formed of two contrasted curves. The overfalling water will drop 98 feet into a basin at the toe of the dam, 15 feet deep, formed by means of a secondary weir having a maximum height of 20 feet and placed across the river 200 feet below the main dam.

The width of the secondary weir will be 13 feet on top and its crest length will be 120 feet. The material is to be rubble masonry bedded in cement and concrete. About 32,000 cubic yards of masonry will be required. The contract for its construction has been let at $10.39 per cubic yard, but this price does not include cement, which is to be furnished by the districts. Its total cost will be about $400,000. The dam will be the highest of its type in the world.

The division of water for the Turlock Canal will be accomplished by means of a tunnel 560 feet long, 12 feet wide at the base, with vertical sides rising 5 feet to the spring of the arch, which will be semicircular with a radius of 6 feet. This diverting tunnel will have its head about 50 feet above the dam, and the flow of water through it will be controlled by means of the gates at its lower end, where the water in excess of that required for the canal, will be turned through waste gates back into the river. For a distance of over a mile below the head gate the canal winds along a steep slaty hillside, and the depth of water proposed is 10 feet. Its bed width is 20 feet, and its lower bank will be composed of dry laid rock retaining walls, having a thickness of 18 inches and inclosing a puddle core of earth 12 feet thick. At the lower



Turlock and Modesto Dam. Turlock and Modesto Irrigation District, California.
Looking up Tuolumne River from point just below dam in process of construction.

end of this hillside work in slate the canal crosses Snake Ravine. The crossing is effected by closing the ravine by means of a dam and turning the canal up the ravine a distance of nearly 1,000 feet, thence out through a cut 800 feet long, constructed principally by the hydraulic process.

Below this cut the canal waters will occupy old mining pits for a distance of over 2,000 feet, and will then flow through another cut in rock for 860 feet, into Dry Creek. The channel of this creek will be utilized for a mile and a quarter, being diverted by means of a flume, and thence westward, piercing three foothill spurs in tunnels, none of which require lining. Below the last tunnel a gulch is crossed above a dam having a maximum height of 40 feet, and the canal enters another cut 3,300 feet long. Peasley Creek will be crossed to a flume 20 feet wide with a water way 7 feet in depth. The canal below Peasley has dimensions adapted to a variety of material into which it is cut, being generally intended to carry water 7½ feet deep on a fall of 1 foot per mile.

At the end of the main canal, which has a total length of about 18 miles, the water reaches the lands of the district and will be distributed by means of five laterals whose aggregate length will be 80 miles. They will carry water 5 feet in depth and will have bottom widths of 30 feet. Their fall is to be 2 feet per mile. In addition to these five principal branches distributaries to the extent of about 180 miles in aggregate length are to be constructed by the district. The sale of the original bond issue will not yield sufficient capital to complete the construction of the entire system of works, and an additional issue of about the same amount as originally voted is contemplated.

The plans for the important work on the dam have been well matured. It still remains an open question, however, whether the work would not be safer if artificial channels had been constructed past one or both of the ends of the structure, with long spill-ways dropping over the natural face of the cañon wall below the dam, rather than to permit the flood flow of the river to sweep over its downstream face. This flood at times exceeds 120,000 cubic feet per second. The enormous pressure belonging to such a flood flow is the basis of the not unfriendly criticism of engineers who have examined this work. The observations made in the summer of 1891 seem to fully justify the caution expressed in the suggestion. The importance and magnitude of this great dam also emphasizes the need of thorough supervision by municipal and State authority of all such structures, so that, in advance of work to be done, reasonable decisions may be reached as to the means and methods of security to be employed and completed.

The Modesto, which is associated with the Turlock in the construction of the division works on the Tuolumne, occupies a position between the Stanislaus River on the north and the Tuolumne River on the south similar to that of the Turlock district between the Tuolumne and the Merced. As originally organized the district embraced within its boundaries 108,000 acres. Based on the engineers' examinations and report, which were not made until an estimate of the cost of the works was required, it was decided to cut from the district boundaries about 30,000 acres of lands in the northeastern portion which had too great an elevation to permit a water supply for the entire district to be secured at the small expense hoped for.

The following extracts are from the report of C. E. Grunsky and refer to the district as originally established:

> Two sources of water supply to be examined were Tuolumne River, which flows south of the district; Stanislaus River, which is north of it. Each of these rivers has a large volume of flow in the spring and early summer months. Both are compara-

tively small streams during the late summer and autumn months. The Stanislaus at Oakdale drains an area of 1,051 square miles; the Tuolumne at Roberts Ferry an area of 1,501 square miles. Taking the years from 1879 to 1884 inclusive, as a basis, the greatest average monthly flow of the Tuolumne River occurs in June, and for that period equaled 8,188 cubic feet per second; the smallest average monthly flow was in September, and equaled 196 cubic feet per second. From September there is a gradual increase of flow till the middle of June. During the same years the greatest average monthly flow of the Stanislaus River was in May, and amounted to 5,290 cubic feet of water per second. The smallest average monthly flows of the Stanislaus River occurred in September, and equaled 127 cubic feet per second, there being a gradual increase of flow from September to the latter part of May.

Based on the experience of irrigators in different parts of California, it is safe to estimate, as fully satisfying all demands of irrigators in this district (wherein sandy soils predominate and the average rainfall is about 9½ inches), that not to exceed 1 cubic foot of water per second will be required for each 160 acres of land from March to June, inclusive; not to exceed 1 cubic foot of water per second for each 400 acres will be required from July to September; not to exceed 1 cubic foot of water per second for each 640 acres from October to December, and not to exceed 1 cubic foot per second for each 1,280 acres during January and February. Water supplied at this rate would be sufficient to cover every acre of ground in the district 1½ feet deep from March to June, 9 inches deep in the next three months, and 2 feet 8 inches deep in the course of the whole year. To supply water at the maximum rate above indicated, the main canal must have a capacity of 675 cubic feet per second.

Stanislaus River may be relied upon to furnish this amount of water, though there will be occasional months (during the season when water is least in demand) when the full amount desired can not be obtained. For the six months from February to July inclusive its average flow is more than four times the amount noted above as desirable.

Tuolumne River ranks equally as high as a source of water supply for this district. It has a more extended watershed and a somewhat greater flow. But it is to be remembered in connection with this river that the requirements of Turlock irrigation district will be united to those of Modesto district. As the former has an area nearly twice as great as the latter, there should be available for both together about 2,000 cubic feet of water per second from March to June, 800 from July to September, 500 from October to December, and 250 in January and February. The river has an average flow adequate to meet this demand, but during the months of least demand for water there will be times when the river will afford less water than desirable (though by no means necessary for successful irrigation), particularly when some allowance has been made for riparian owners.

It was found that the highest land in the district is near its northeast corner, and that to accomplish its irrigation the actual elevation of water must be 30 feet higher than that of water at the cañon mouth of the Tuolumne River, about 200 miles above La Grange. The low-water plane about 2 miles above Knights Ferry, on the Stanislaus River, is barely higher than the highest ground of the district. The former of these points lies 21 miles in the district line from the northeast corner of the district; the latter is 11 miles distant. It was found impracticable to carry water on the riverside of the hills along the north bank of the Tuolumne and hold the same high enough to cover these high lands. Nor is it practicable to carry water to the south side of the Tuolumne and hold the same high enough. It is however feasible to direct water from the Tuolumne River into Dry Creek and thence by means of a small ditch to carry some of the diverted water to the highest lands of the district, while the main volume is permitted to flow in Dry Creek, a distance of 24 miles to the district lands. It is equally feasible to direct water from the Stanislaus River at a point about 2 miles above Knights Ferry at the lower end of Twomile Bar, and to carry it thence in a direct course to Buena Vista, thence across the gravel flat below Buena Vista to Wildcat Creek, in a flume across Wildcat Creek to Wildcat Ridge, along the face of this range of hills about one half mile, thence through the same in a short tunnel to Haskell Creek channel.

From Haskell Creek the water can be diverted sufficiently high to cross a divide about three-quarters of a mile south of the Lancaster place, whence the water would command nearly all of Dry Creek Valley. From that point the route of the main branch of canal to the district would be along the gentle sloping hillsides. Water brought into the district along this route would be high enough for all its irrigable lands.

At the lower end ot the Twomile Bar, where the diversion of water from Stanislaus River must be made, there is an excellent site for a dam, and material for its construction is convenient and abundant. It will be necessary to raise the water surface at that point about 90 feet from extreme low water to the level of the water surface in the canal, in order to make it possible to keep the canal on the ground favorable for canal building. The probable cost for works for irrigating the whole district from Stanislaus River was estimated at $644,750 (not including right of way).

Referring to the question of irrigating the district by means of a canal from Tuolumne River, Mr. Grunsky says:

> It is less expensive to direct water from the Tuolumne River at or near the cañon mouth by means of a high dam than it will be to direct it at some point further up stream by means of a low dam and carry it in an expensive canal along the cañon wall. Dry Creek Valley at its head has an elevation of 130 feet greater than that of natural low water at the cañon mouth of the Tuolumne River. It will be necessary to raise water about 140 feet at that point to afford the necessary fall for a canal from the river to the creek.

This project would have involved the construction of three tunnels 2,800, 1,500, and 600 feet long, respectively, and the cost of the whole works, including distributaries throughout the district, was estimated at $1,118,000. After mature deliberation a bond issue sufficient to carry out the Stanislaus project was decided upon, and the bonds were voted to the extent of $800,000; but it was also decided that the interests of the land owners throughout the greater portion of the district could best be conserved by amending the district boundaries and excluding the high northeastern portion thereof. This was done, and the highest points in the district are now about 70 feet lower than at the time when engineer Grunsky made his surveys.

After additional surveys for the amended district were made by P. Y. Baker and F. G. Brooks it was finally decided to unite with the Turlock district, and to construct a joint diverting dam across Tuolumne River at the mouth of its cañon just above La Grange. The plans for this dam, devised by Luther Wagener, engineer for Modesto district, were accepted and its construction has been commenced. This has already been sufficiently described.

It is now proposed to construct the main canal along the foothills and on the flats upon the north side of Tuolumne River, a location which was not feasible before district boundaries were changed. The canal work will be very expensive near its head, but comparatively inexpensive after it has crossed the broken country within 5 miles of its head.

The lands of the district are for the most part sandy or sandy loams, but little of the heavier clayey soil near the base of the Sierra Nevada foothills being included within the district boundaries. The general land surface of the district is smooth; the slope is from east to west and ranges from a little less than 5 to about 10 feet per mile. Nearly all the land is devoted to the cultivation of cereals. The plains in their original condition were treeless. The lands of the district will be well adapted for intensive farming as soon as water is made available. The district has an area of 81,500 acres and extends from near the eastern edge of the San Joaquin Valley westward to the lowlands adjacent to the San Joaquin River.

These systems have been particularized somewhat at length, so that intending irrigators and others interested may obtain a reasonable idea of the methods required for the organization of district administration and the work of construction under the important irrigation and water code of California.

In the counties lying outside the great basin of the San Joaquin and Sacramento the seepage or the filling of the ground with water will play but a small part. The rivers are small and rapid in course, and the increase of the areas of irrigation by the water in sight must be accomplished by economical distribution. In many places in the Southern counties where irrigation has been practiced for a long series of years the soil has not been wet all the way down, and a cubic foot of water irrigates no more land to-day than when the ditches were first taken out. This condition has necessitated the adoption of pipe lines and cemented ditch systems. The great profit accruing from the culture of the citrus fruits, and the tropical abundance in which the more delicate vegetables are produced, have given the irrigators in the Southern counties ample means to pay for the expensive works rendered necessary. The costly works of the Turlock and Modesto irrigation districts, pro-rated to the acres, serve to make a lien per acre of but $9.81 in the Modesto, and $3.40 in the Turlock district. This is explainable by the fact that the two canals will irrigate more than 550,000 acres. While the five districts in San Bernardino County—Alexandro, Citrus, Belt, East Riverside, Grapeland, and Rialto—have been bonded at an average of $53.94 per acre for their water service, and but 58,787 acres are to be irrigated.

The Sweetwater dam, in San Diego County, is an example of the great energy. skill, and money that have been put into the development of a water supply. This work has been previously described.

The Bear Valley system, a short history of which was given in the Progress Report of 1890, is here again described because of the more accurate data obtained. The work now constructed and projected will eventually bring about 450,000 acres under intense cultivation. The credit of projecting this vast work belongs to Mr. Frank E. Brown, C. E., of Redlands, and the skill and daring with which his designs have been executed have developed the highest type of systematic irrigation on this continent. It is greatly to be regretted that the limited means and time at command prevent the production of a relief profile map of the catchment and irrigated areas involved. It will be seen that the Bear Valley reservoir is only a part of the great plan which Mr. Brown is carrying out. The bold structure at that point as at present standing is, however, worthy of particular and especial mention because of the fierce criticism aroused by its projection and subsequent construction.

The office of Irrigation Inquiry has made a special examination of this work. The structural character of the cross section of this dam has often been severely condemned, and while its duplication could not be recommended, the principle involved by it—that of the upstream arch dam for the formation of reservoirs on sites where the basin narrows into a rock bound gorge, is to be credited with great resisting power. The character of the abutments must however be carefully examined and tested, as the slightest fault at the point where the dam keys into the natural formation may prove fatal. In the Bear Valley structure the natural advantages for a work of this character can hardly be improved upon. At the point where the present dam is located the basin of the Bear Valley narrows until the cañon is almost closed, and the rocky sides of the mountain spurs descend precipitously. A bird's-eye view of the mouth of this reservoir would present an appearance like that of a bladder with a short section of the neck attached turning back on itself. At the turn of this outlet, with its arch force straight into the confined water, is placed the dam. The spillway is entirely separated from the dam, and is blasted out of a spur of live rock into which the dam is keyed. Owing to the peculiar nature of the gorge, unless the precipitation upon the catchment area should become too heavy for the spillway of 24 feet wide and 28 feet deep, the dam could never be subjected to an unusual pressure. This dam will soon complete its eighth year, and in the opinion of the engineer whose reputation is involved can be disturbed by nothing short of an earthquake. Whether a stronger constructed cross section would withstand such a force need not be discussed. The new dam will however be subject to no censure for want of resistance to either gravity or static inertia, as the dimensions given will show. The same bold intellect that created the Bear Valley dam is at work on the no less notable project of a system of reservoirs, including those of the White Water and San Jacinto. The first will make it possible to practically distribute water that falls on one side of the San Bernardino Range upon the other slope. The areas to which this water will be distributed lie in two counties, San Bernardino and San Diego; and those acquainted with the region will be struck at once with the simplicity of the design and the vast conception of engineering forces brought into play. The Bear Valley Company, while developing the greatest system of hydraulic works in connection with American irrigation, is also to be commended for equal foresight in its readiness to conform to the expressed wishes of the people and laws of the State. It was probably the first corporation in California to encourage the formation of the irrigation districts within the area commanded by its pipe lines and ditches, and the same broad conceptions that have marked its engineering department are followed in its dealings with the users of water.

The Bear Valley Land and Water Company was organized in the summer of 1883, and a force of men immediately put to work. About 250 cubic yards of masonry were placed in the foundations of the dam that fall before the snow and ice of winter compelled an abandonment of the work for the season. Early in the spring of 1884 the work was resumed and pushed vigorously throughout the summer and fall, the dam being completed as it now stands in November of that year.

The location is in the San Bernardino Mountains, about 18 miles air line northeast of Redlands, and 6,400 feet above sea level. The structure is of granite rubble in Portland cement, mortar resting on a foundation of solid granite in place. It is curved in plan, having a radius of 335 feet measured to the lower face, which is vertical. It is 64 feet high from the bed rock to the top of the coping and has a length of 250 feet on the crest. The back or side next the water batters from a thickness at the top of 3 feet 2 inches to a thickness of 8 feet 6 inches at a depth of 48 feet; at this point an offset on either side increases the thickness to 12 feet, and from here down a batter on either side increases the thickness to 20 feet at the bottom.

This dam backs the water 5 miles up the valley, and covers 1,859 acres at an average depth of 14¼ feet. The cost of the dam was about $120,000; this cost being greatly augmented by the fact that the cement and supplies had to be hauled by wagon a distance of 100 miles over a mountainous road. The catchment basin has an area of about 77 square miles, and the average rainfall for the last seven years has been about 53 inches per annum.

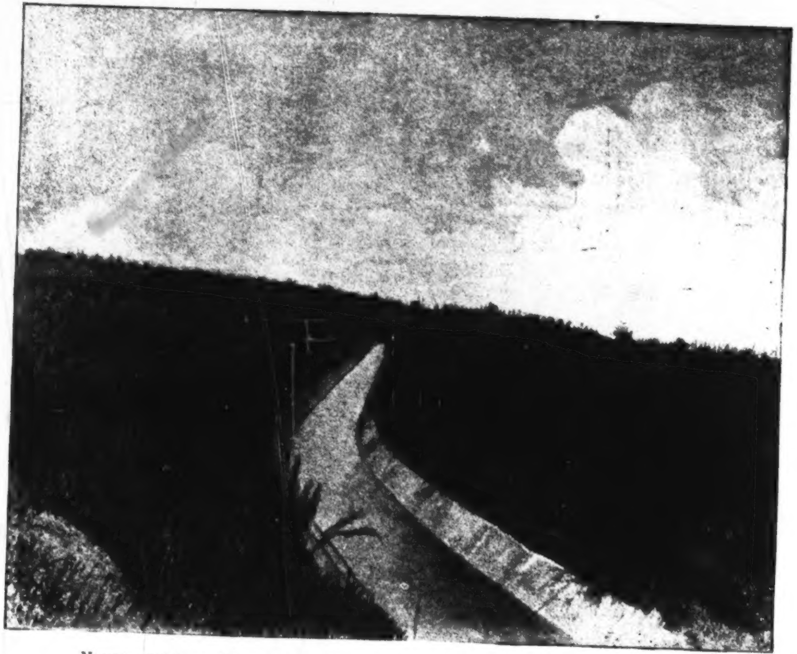
In the year 1890, the Bear Valley and Alessandro Development Company was formed, owning 21,000 acres of land in the Alessandro Valley and a controlling interest in the Bear Valley Land and Water Company. Later these two companies were consolidated and reorganized as the Bear Valley Irrigation Company. The latter company now owns all the property, rights, and franchises formerly held by the other two, and in addition has acquired by purchase various other reservoir sites and water rights, including the right to the entire flow of Whitewater River, Mission Creek, Snow Creek, and the Santa Ana River, and the surplus winter waters of Mill Creek. Heretofore the irrigating power of all these streams has been limited to the extent of their capacity for supplying water by their natural flow in the dry summer months, and still further reduced by the wasteful methods formerly in vogue, of conveying the water in open ditches, running sometimes for miles through the loose sand and bowlders of the river washes, and losing a very large percentage of their waters by seepage and evaporation.

It is the design of this corporation to not only greatly increase the irrigating power of these streams by constructing better and more permanent forms of conduits, but also to augment the summer flow by running tunnels to bed rock from the sandy beds of the stream, thus intercepting the underflow and conveying it to the surface, also by constructing great reservoirs to impound the surplus winter water. To this end many miles of the main and lateral canals have been paved and cemented; over 120 miles of steel, vitrified clay, and cement pipes ranging in bore from 30 inches to 6 inches have been laid; over 2,000 feet of tunnel has been run in the bed of the Santa Ana River, and as many more feet bored through the rocks; plans have been made and work begun on a new and higher dam at Bear Valley which will multiply the present storage capacity many fold; and various other reservoir sites have been purchased. Among the latter is a reservoir site on the Santa Ana River at an elevation of 4,500 feet, which will impound about 12,000 acre feet of water; another in the San Jacinto Valley, which will hold about 120,000 acre feet; and still another in the Potrero Valley, which will contain about 30,000 acre feet. Work is now in progress on all these various sites excepting the Potrero, which has not yet been started. These reservoirs will be pushed to completion in the order in which it is expected that the demand for irrigating water will occur, holding the stored water several years ahead of the probable demand.

First in order is the new Bear Valley dam, the foundation of which is now being prepared immediately below the present dam. Plans had been prepared to build this dam to a height of 129 feet from bed rock to the water line, which will raise the level of the lake 67 feet above present high water, backing the water 12 miles up the valley, and increasing the storage capacity to 461,650 acre feet. Owing to changed conditions brought about by acquiring new reservoir sites at lower levels which will answer the purpose of conserving a larger proportion of the surplus winter water at a less expense, and reduce the length and cost of canals necessary for conveying the water, it has been decided to stop this dam at a height of 89 feet from bed rock for an indefinite period. This will raise the level of the present lake 27 feet, backing the water a distance of 7 miles, and submerging 3,300 acres to an average depth of 29 feet, thus storing 95,700 acre feet. This, with the 12,000 acre feet to be impounded by the auxiliary dam in the Santa Ana Cañon, will in all probability be an ample supply for all available lands lying between the level of the head gates of the canals in the Santa Ana Cañon and the level of the great storage reservoir in the San Jacinto Valley.

Next comes the dam in the Santa Ana Cañon; this will be of stone, 175 feet high and about 300 feet long. A tunnel, 750 feet long, through solid granite and large enough to carry the ordinary flow of the river, is nearly completed for the purpose of acting as an outlet for this reservoir, and for diverting the stream while the dam is being constructed. As soon as the tunnel is ready, active work will be commenced on the dam itself.

The reservoir site in the San Jacinto Valley is a depression in the midst of a rich alluvial plain, where the San Jacinto River broadens out, forming at high water a considerable lake or laguna, as such bodies



Modern "Cement" Ditch. Bear Valley System. Redlands, California of water are locally called. The outlet to this lake is a narrow opening less than 1,500 feet in width, passing between two low ranges of mountains, and it is at this point that the dam will be constructed. A large number of borings have been taken at the proposed site of the structure showing the substrata to consist of alternating layers of clay, sand, and gravel to a depth of 60 feet from the surface. This dam will submerge 9,300 acres to an average depth of 12 feet, thus storing 116,000 acre feet of water. Artesian wells flowing water under a considerable pressure have been found in the region of this lake, and although they will not be relied upon as a means of filling the reservoir, yet it is expected that they will go very far toward compensating for the inevitable loss by seepage and evaporation.

This great reservoir is to be filled during the flush winter and spring months, partly by the San Jacinto River and partly by the Whitewater, a mountain stream, which will be diverted at a point about 30 miles distant and conveyed to the reservoir partly in pipes and partly in open paved and cemented canal. These works will have carrying capacity of 15,000 miner's inches, or very nearly two-thirds of that of the new Croton Aqueduct. Later another aqueduct turning the surplus waters of the Santa Ana River and Mill Creek into the same reservoir will be constructed. The Potrero Reservoir proposed is not yet begun, but it is probable that a stone dam impounding about 30,000 acre feet will be constructed at that point.

Originally in the distribution of water, the Bear Valley Land and Water Company adopted the method of issuing certificates per acre entitling the holder to the right of using one-seventh of a miner's inch of water perpetually; these certificates were transferable, and were supposed to represent water sufficient to irrigate one acre of land. Of these, 7,200 were issued to the stockholders in lieu of dividends; two certificates to each share of stock. They are liable for an annual assessment or tax for the purpose of maintaining, repairing, or reconstructing the canals through which the water flows.

The present Bear Valley Irrigation Company has adopted a somewhat different method of distribution, having issued 100,000 certificates entitled "Class B" acre water-right certificates. Each certificate entitles the holder to 1 acre foot or 43,560 cubic feet of water each year, and the holder of each certificate pays to the company an annual rental of $2.78. Under these certificates and within certain prescribed maximum limits the owner may accumulate the water so as to use more in the dry summer season and less in the winter. Of these acre water-right certificates 51,000 have been sold to the Alessandro irrigation district; 16,000 sold and 5,000 more contracted to the Perris district, and 8,000 have been contracted for by the Elsinore district. The water is conveyed by the Bear Valley Company to some point agreed upon, generally within the irrigation district, and there taken charge of by the district authorities.

The form of conduits vary according to conditions, nature of country traversed, and character of service required. For the country about Redlands, Crafton, Highlands, and North San Bernardino, a region of great beauty and fertility, having a considerable population, open canals of a trapezoidal cross section, paved and cemented on the bottom and sides, are used, the paving being of granite bowlders from 6 to 10 inches in diameter, and the mortar composed of Portland cement and sand, costing when laid in place about 13 cents per square foot of surface covered. Where possible, these canals follow the contour of the country, on grades varying according to the capacity of the canal, so as to give the water the velocity of from 2 to 5 feet per second, it being found by experience that with velocities much below 2 feet per second the channel will become obstructed with aquatic vegetable growths, and with velocities greater than 5 feet per second the erosion will be so great as to seriously injure the cemented bottom of the channel.

Pipes and wooden flumes are used where necessary when crossing depressions. A wooden flume in the Santa Ana Cañon has been replaced with a wooden pipe 48 inches in diameter inside. This pipe is 2,000 feet long, and is built up in place with staves of California redwood and banded with hoops of round iron five-eigths and three-fourths inches in diameter. The hoops are spaced according to the pressure to which the pipe is subjected; the lowest point in the depression being about 45 feet below the hydraulic grade line, the hoops at this point being three-fourths inch round iron, spaced 7 inches apart. The top of the entry end of this pipe is level with the bottom of the delivery end, so that no matter how little water is running, the pipe will always be full. The entry end of the pipe starts from the bottom of the vertical penstock or forebay, which gives the water the necessary head for forcing it through the pipe. The present capacity of the pipe is about 4,000 miner's inches. When, in future years, it becomes necessary to force a larger amount through the pipe, the water will be delivered in the forebay at a higher level, thus giving the pipe the additional head required. The staves of the pipe are 2¾ inches in thickness, being taken out of 3 by 6 inch timber, and machine dressed to the true curve inside and out. This pipe has been in use for several months and so far has proven entirely satisfactory. It rests on redwood sleepers placed transversely 10 feet apart and about 1 foot above the surface of the ground. The entire cost, exclusive of grading, was $3.63 per foot.

Another notable pipe is the one leading the water from Mill Creek to the Alessandro irrigation district. This pipe is made of riveted steel and is 10 miles long. The first 2 miles is 28 inches in diameter and the balance is 24. The sheets vary in thickness from No. 14 to No. 0 by the Birmingham wire gauge, the thickness increasing according to the pressure to which the pipe is subjected. The lowest depression on this pipe line is 400 feet below the hydraulic grade line. Blow-off gates are provided at all depressions, and automatic air valves at all summits. The capacity of this pipe is about 1,000 miner's inches. The total cost of the line complete, including cost of 4,000 feet of tunnel, was $210,462. There is also a few miles of cement pipe ranging in size from 6 to 30 inches. For the most part they are composed of Portland cement and sand in the proportion of 1 part of the former to 4 of the latter. They vary in thickness of shell from 1 to 2½ inches, according to the size. They are made by a hand machne in 2-foot lengths and are seasoned in the air twelve days before laying, being kept sprinkled with water all the time.

The joints are put together in the trenches with strong cement mortar, thus forming a continuous pipe. This kind of pipe, though largely used in the past, has not proved entirely satisfactory. A better class of pipe is the ordinary salt glazed vitrified clay sewer pipe, and of this kind the company have already laid over 32 miles in sizes ranging from 6-inch up to 24-inch. By doing a careful job of laying, this pipe can be placed under heads of 20 to 30 feet safely. In cases where it is necessary to subject the pipes to greater pressure, as for instance, where orchards are planted on rolling land or hillsides steel or iron pipes are used. In such cases, if the hills are very steep, they are terraced; if the slope is more moderate the trees are planted around the hills on contours having a fall of 2 or 3 inches from tree to tree. At irrigating times furrows having a uniform fall are run around the hillsides above the rows of trees, and these furrows are supplied with water from hydrants tapped into the main pressure pipes which follow the higher ridges of land. All canals, conduits, and pipe lines are under the immediate care of division superintendents, called by the Spanish name, zanjeros.

A person wishing to irrigate his land gives notice to the proper zanjero three days in advance, stating the quantity he requires, and the water is delivered to him through a pipe and hydrant, and is measured over a weir at the highest point of his land. From here it is usually conveyed in small wooden flumes or cemented brick ditches, and delivered to the heads of the irrigating furrows through holes in the sides of the flume or brick ditch.

The same parties also own the surplus carrying capacity of the North and South Fork canals, taken out of the Santa Ana River at its points of emergence from the cañon. The North Fork will be extended westward to cover about 10,000 acres in the Muscupiake Ranche, near the city of San Bernardino; and the South Fork will furnish water for the irrigation of the Lagonia and Sunnyside settlements in the eastern portion of the San Bernardino Valley. One result of the course followed by the management is the gradual replacing or abandonment of the old ditches made by the Mexican or early American settler. This change may be regretted by the lover of the picturesque, for their course is marked by the verdure of trees and indicated by luxuriant undergrowth, but they are exceedingly wasteful, often failing in supply when most needed. The new policy guarantees each user the amount he claims from the older ditch. He claims but often fails to receive.

Mr. L. M. Holt, the editor of the Orange Belt Redlands, Cal., is a very close observer of the progress of irrigation in California. He has been identified with the growth of the system almost from its birth, and his opinions are of great value. The following interview giving the history and application of irrigation in the southern section with the special agent will be found valuable in connection with the district system. The application of the principle of the Wright law as discussed by Mr. Holt opens large avenues for successful investment and great opportunities for popular development of homes. He says:

> The old style or old school of irrigation practiced in the coast valleys in this State is nearly exhausted. The original bringing out of water here was in crude open ditches when it could be brought out of the running streams and put on the lands within the river valleys, when it could be gotten out the cheapest and was not applied to the mesas at all. It was not until 1872 at Riverside that any attempt was made to irrigate the mesa lands.
>
> In 1875, the original Pomona Canal was organized on the basis of the ownership of the water by the users of it, a share of stock to go with each acre of land. I was secretary of that colony. That was followed by the Redlands Company, the Etiwanda Company and the San Antonio Canal to irrigate Ontario. In 1884, the Riverside people pulled out to fight the old company, bought them out and organized on the same plan. In 1880, there was only considered to be enough water to irrigate 10,000 acres of land in San Bernardino County. In 1890, with improved methods for the storage and development of water, the area has increased until it is now estimated that 140,000 acres can be irrigated. Up to 1880, the open ditch was the only system, and from that until 1890 there were other methods. We commenced cementing the canals to save seepage, and adopted flumes and pipe lines; and instead of distributing the water in ditches in southern California it is done now almost entirely by cemented, vitrified, wooden, or steel pipes. Redlands was the first to take up the pipe system, then came Ontario. When we got all of the streams utilized there came the proposition to use more water. It could only be done in three ways, by artesian wells, tapping the underflow, or by storage. Ontario was the first to adopt the artesian system. The Gage system adjoining old Riverside was the next one.

They depend entirely upon artesian water. These are the only two places that have adopted artesian systems to utilize water on the mesas, that is, taking the water from the moist lands out on the mesas. The water here on the mesa is found only in the cienagas. In 1882, Frank E. Brown, of Redlands, had to have some water for his settlement, and I suggested to him to use the underflow of the Santa Ana River, and that was the first time the utilization of the underflow was broached. I knew there was an underflow, and I was satisfied that there was a bed rock under the stream and that this bed rock was holding the artesian flow below; and if the bed rock was not too deep you could develop this lost water of the rivers. Another proposition was that the further up the stream you went the more water you found in a given area. He adopted the plan and is now gradually completing his tunnel and getting a considerable supply. The next year I suggested the same thing to George Chaffey for his canal, and took him up to Brown's tunnel, which had 40 inches of water in it developed from a bowlder formation in which you would not think there was any water. That tunnel is now up to bed rock, and they are drifting out from the upper end to let the water in from above.

Q. Now, your acquaintance with this mountain region is very intimate, and I should like to know your idea as to the possibility of extending or developing its underflow. As progress goes on, there must be unquestionably many small settlements in the valleys here that would get no water from the surface that might be reclaimed from phreatic sources. What is your view?

Mr. **Holt**. There is no question that a tunnel up into any of the mountain cañons will develop water; but the cost of it is so great that it will not pay to do much of that work so long as you can get a good supply from a storage system. In 1883, we began the adoption, and in 1884 the first reservoir was completed in Bear Valley. It was an experiment for six years. People did not have confidence in it; and under the laws of the State, as we had them at that time, there was no practical way of placing water on the land; and if it had not been for the passage of the Wright law the storage system could not have been adopted with any degree of success, and the Bear Valley enterprise would have been a practical failure. That company has authorized the issue of what they call "acre water-right certificates," each water right calls for an acre-foot of water during the season, or for a supply sufficient for an acre of land. In this way the water is wholesaled to the district.

In the way water is used in California an acre-foot of water will supply an inch to 8 acres during the summer months and will give all the water that is needed for the balance of the year on the basis that about one-half of the entire supply is called for in June, July, and August, and only one-fourth during the months from November to April, and the other one-fourth during the other three months. On these lines an acre-foot of water will give 1 inch to 8 acres, and all acre water rights are on that basis. They sell acre water rights to a district. The district can buy as many as they want. They can buy 1 inch to 8 acres or 1 to 4, just as they please, or often more. It was thus that the organization of districts made it possible to make this wholesale storage and commerce possible. But in the management of distribution the reservoir people have no existence; the district takes what water it wants and distributes it to satisfy itself. The Bear Valley, having secured its legal rights of appropriation and storage, is necessarily in harmonious relations with water districts. There is no likelihood of an attack on the company. The people of the small districts look upon it as their friend; that is, they can get water cheaper that way than to try to store it themselves. Under the system, then, it is calculated that they will irrigate from 400,000 to 500,000 acres of land in San Bernardino and San Diego counties.

Q. The organization of the Bear Valley and other enterprises, with accompanying colony methods of land settlement and cultivation under them, appears to me to have carried the irrigation areas onto higher altitudes; that is, it comes up into these intramountain valleys and affords, as I see it, a very extended possibility of reclamation. Can a system similar to the Bear Valley be applied to the Antelope Valley, for example?

Mr. **Holt**. The trouble there is the rainfall areas. The rainfall in the mountains is about five times what is in the valleys; and therefore 100,000 acres of valley land will not get more moisture than 20,000 acres of mountain land. The average fall in Bear Valley has been 60 inches. Last winter there were 31 inches of rainfall in forty-eight hours, and the water raised in the dam 2 feet in twenty-four hours over that immense lake, notwithstanding the fact that at the outlet, 24 feet wide and 28 feet deep, the water was running out all the time. The water supply in this section for the future must be gotten almost entirely by storage reservoirs in the mountains. A storage reservoir within a valley watershed is of no account in this country. One reason of that is the smaller loss in the mountains. There is less evaporation and larger rainfall, and you can save a large percentage of it.

Q. Taking generally the situation of irrigation as a matter of peace and order on one side, of business security for the investor and user on the other, and also of future

"Zanja," or Old Style Open Ditch   San Bernardino County, California.

development, what has been the effect of the passage of the Wright laws, taking first Southern California and then the whole State, as you know it?

Mr. HOLT. It has had the tendency to settle all disputed water claims and to develop our water resources very rapidly. We have at the present time (June, 1891) about thirty districts in the State. There have been a few others that have tried to organize or organized illegally, but there are about thirty districts in all. They have voted about $13,000,000 in bonds. There have been about $4,000,000 of these bonds sold either for cash or traded for water-right certificates, and in the history of the State there has never been anything like the development of the last four years. The supreme court has decided the system constitutional and stood by the districts in every way. The financial public is beginning to appreciate the value of such securities, and money can readily be had to carry on the work. Mr. Adolph Wood, of the Arrowhead Reservoir Company, told me that if it had not been for the passage of the Wright laws his company would never have thought of putting its money into a reservoir system.

Q. Has the effect of the district system as applied to water and water-works ownership and the settlement of legal questions been such as to content capital with the profitable repayment of its money invested, and to get rid of the idea of its controlling the works and the water for all time?

Mr. HOLT. Yes, sir; the old feeling of antagonism has vanished to a certain extent. The districts recognize the fact that it is impossible for the people to go into large propositions of reservoir storage, because one system may be large enough to supply several districts; and if a district can have a certain amount of water delivered properly they can afford to pay a certain amount of money instead of keeping up the existence of a reservoir large enough to furnish other districts. Then, information has tended to remove all the former quarrels, disturbances, and disputes that existed between the corporation and the users of water. This is one of the principal effects. It is a recognized fact that these districts can exercise the right of eminent domain and condemn water if it can not be obtained otherwise; and after a district is once organized the canal companies do not stand out to litigate, but take any good price. The bonds are considered sound. The only question with the companies now is how many they can get. Riverside is practically a community effort, in the sense of that term, because the stock is centered among the owners of the land; and the same is true of Etiwanda; but at Etiwanda they are discussing the proposition of putting the community stock into an irrigation district. At Etiwanda there are some conflicting interests that can better be settled by a district than by the owners of community stock. The original projectors had a contract by which they had the right to develop water for fifteen years, and that contract is about to expire. They had the right to measure the water on the 15th day of August and call for more stock on account of any water developed; and they are rather anxious to crowd that proposition by taking the measurements in wet years.

Q. In watching the operations upon the western half of the arid region have you ever thought of the possibility of extending the district system over the public lands therein by the coöperation of the State, Territory, and United States?

Mr. HOLT. I have thought of that and it has occurred to me as being about the only way that the question could be practically reached. Some modification of our State law would perhaps have to be made in order to make the system fit well with somewhat different conditions.

The proposed Arrowhead reservoir system in San Bernardino is another notable water-storage proposition. It is the outgrowth of the peculiar situation of southern California, and has received its direct stimulus, according to the engineer's statement, from the adoption of the Wright laws. The watershed lies north of the San Bernardino Mountains, embraces about 75,000 acres, includes Deep Creek and the East and West forks of the Mohave River. There are to be four reservoirs linked together and above one another, so that if one breaks its flood will be emptied into the others. The highest reservoir is located in what is known as Little Bear Valley. That basin empties into the Deep Creek Reservoir. The Little Bear Valley is connected with the Deep Creek watershed by a canal which starts at the mouth of Holcomb Valley, and, winding around, intercepts the tributaries of Deep Creek. This canal is 17 miles long, and its water is conveyed in a northeast direction into Grass Valley. From there the canal is continued southwesterly into Houston Valley, and from thence the water is conducted into Seeleys Valley, at which point the water is taken into a tunnel about a mile through the mountains that empties into Cañon Diablo. The Arrowhead watershed begins on the divide between Bear Valley and Little Bear Valley. There is an estimated annual rainfall of about 60 inches, and besides this there are large cienegas and enormous springs emptying into the catchment basins. The altitude of the catchment basins varies from 4,800 to 8,300 feet above sea level. The irrigable area begins at the mouth of Cañon Diablo, where the mouth debouches into the valley lands. Five engineering parties were in the field in July, 1891, and a road 17 miles long had been constructed into the mountains. It is claimed that all the country lying in the direction of the Riverside settlement and between them and the Arrowhead may be irrigated from the reservoirs proposed. This company has been organized for the special purpose of selling water to irrigation districts. And this determination indicates an understanding of the sagacious policy first pursued in southern California by the Bear Valley Company and its astute directory.

The vital question in the future of irrigation cultivation, so far as the fruit-growing sections of California south of the Tehacapi Range is concerned, is bound up in the matter of storage. No more profitable investment can be found there than the control of a good catchment area, with appropriate storage sites for holding and conserving the precipitation thereon. It is not difficult, then, to perceive the force of the testimony given the office of irrigation inquiry, to the effect that such investments are made more secure as well as more profitable by reason of the adoption and enforcement of the laws providing for the organization of irrigation districts, for the distribution and management of water. The Bear Valley managers were emphatic in testifying to the special agent that they could not successfully carry on their great enterprises by dealing directly with individual users of water. Hence they have, as business men, done all that is possible to facilitate the organization of districts to be supplied from their storage system, recently increased, it is reported, by appropriations to cover 200,000 additional cubic inches of water. The individual irrigator is too often inclined to litigation. He is always complaining. With the district authorities the storage company claim to be able to deal on the plane of public interest. This, at least, is their testimony. In its degree it is a remarkable tribute to the value of the Wright laws. But it presents another feature which operators in and organizers of storage works will have to take into consideration; that is, the fact that the district system is the logical outcome of the social economic necessity which, wherever irrigation is the essential need of cultivation, must make it tend rapidly to the policy of public control, ownership, and management of water and works needed in any community for the maintenance of agricultural security. The Wright district system in California provides for the public control of storage areas and works as much as it does for distribution and management. This is logically embraced within the laws, but as a practical fact it has so far escaped its operations. As the land laws of the United States permit the appropriation of water for beneficial use on the public domain, the majority of storage areas and sites are being taken up. In California a still larger number of appropriations were under the control of Spanish and Mexican land grants. But the power to direct the disposition and use of water for beneficial purposes remains with the State. It has been exercised most wisely in the matter of irrigation district organization. The question is sure arise whether or not the State will exercise its powers of sovereignty and eminent domain at some not distant day, so as to transfer by law, amicable purchase, or legal condemnation, the great storage reservoir systems that now exist or that will be made ready for operation. It is quite certain if it is ever done it will be on grounds of the highest public needs and upon full compensation for all investments. Such possible action is in the logic of the situation. In the meanwhile there are large returns awaiting enterprise in this direction and a certain continuance of profit in the bond income that would follow a transfer to State or district.

During the next two years in California there will be added to the area reclaimed in this State, by works now in process of construction, more than 2,500,000 acres of land. This great advance has been the result, primarily, of the passage of the Wright laws. The opposition, so bitterly pressed, to the operation of this statute has had one valuable consequence. The bankers and moneyed interests of the State determined last summer with the assistance of J. W. Nance, president of the State association of irrigation districts, to make a close examination into the physical, engineering, and business problems and conditions of the districts, together with a statement of the legal status of each. Messrs. Wilson & Wilson have been retained to report on the legal problems involved, and Mr. Wm. Ham. Hall, ex-State engineer of California, has charge of the economic and business side of the investigation. The work, so far as completed, has been ably done. Only three districts, however, have been examined and reported on, *i. e.*, the Central, the Perris, and Alessandro irrigation districts. These reports have been made respectively on July 25, August 15, and October 1, 1891.

The matters examined and reported on include the physical data of each district, its adaptability to and necessity of irrigation, water supply, duty and delivery, works, cost, district valuation, and bonded indebtedness, present and future financial condition and outlook, irrigation bonds, rights of way, contract rates, cost of irrigation, character and condition of the work and its probable effect, together with a report on all litigation, and the tenor of local sentiment for or against the works and projects of each district. All these points are carefully and ably considered. In the report on the Central district, discussing the necessity of irrigation therein, Mr. Hall makes the following interesting comparison:

> The valley of the Po, in Italy—the classic land of irrigation—although it is most copiously watered by nature's methods and processes, is, also, artificially irrigated more freely and fully than it is proposed to irrigate in any district of this comparatively very dry California. The Italian valley, in form and in size, is almost the counterpart of our Sacramento. It receives on the average, according to special locality, from 22 to 35 inches of precipitation annually, as against local annual averages of 14 to 21 in our Sacramento Valley. And yet in that special region in the valley of the Po, embracing a great extent of country, where the rainfall averages about 30 inches per year, and is much better distributed through the months than with us, irrigation is practiced to that extent and intensity that the cubic foot of water per second serves only 60 to 70 acres of land, while the same volume of flow is expected in California to meet all demands on at least two or three times as great an acreage. But that Italian irrigation serves to support 200 or 300 people per square mile; and though rainfall is so copious and well distributed, the artificial application of water is just as necessary to the support of that population as it would be to the support of 20 to 30 people, even, to the square mile on one of our driest and least productive plains. Without irrigation, about the same proportion of both populations would have to emigrate or die.

Discussing the supply and duty of water, the report proceeds:

> There is an abundance of water to spare in the Sacramento River to supply the Central irrigation district canal to the utmost capacity now projected, namely, something less than 750 cubic feet per second.

There are no other canals diverting from this source, except some insignificantly small ditches. There are no other works in course of construction, or claims to water likely to interfere with that of Central irrigation district.

This supply, at the rate of 1 cubic foot for 150 acres is amply sufficient for the class of cultivation likely to be practiced in the district. The area of the district is 156,550 acres, which, minus 10,000 taken up with public and private rights of way, will afford 146,550 acres that may be actually cultivated every year. The value of land with and without irrigation in the Central district is repored:

It is generally considered that wheat-raising, as a business on fair to best lands, when conducted systematically in large tracts in the region of this district, justifies land values of $30 to $50 per acre. If we were to judge these land values from the rates per acre thus far paid for right of way for the main canal of this district, even allowing largely for the element of damages to the other acres of the tracts crossed, by reason of the presence of the canal, we would be led to fix upon valuation materially in excess of the above.

In my opinion, the farming lands alone in this district (rated as a savings bank would rate property in California, in considering it as security for a loan), are worth on the average $30 per acre, or, say, $4,500,000. It is not necessary for the purposes of this report to try to make any estimate of, or express any opinion on present values of other district property.

If irrigation is introduced and well administered, and the farmers profit by it as fully as they should, and demonstrate their ability to, and intention of so profiting, within five years after water distribution commences in this district, its farming lands, by that time being extensively planted to fruit and sown in alfalfa, should, in the light of abundant experience in this State, be worth, as mortgage securities, $9,000,000. Be it remembered that every acre of the district would have a water right attached to it, and that the annual cost of irrigation would be the expense of administration, maintenance, and interest on bonded debt; and that each acre would have its cash value reduced, by reason of that debt to the extent of its share of it.

The total assessed valuation of property in the district is now $2,720,770. In my opinion it is altogether within limits to assume that as soon as irrigation is brought to command the lands of this district, its taxable property may be valued, as such valuations are here made for tax assessment, at $3,000,000; and that if irrigation is extended with any reasonable degree of progression, as compared to rates of advance made under similar conditions elsewhere in California, an additional $250,000 of valuation per year, on the average, might be added to the roll for each following year, until the bonds can have been paid off.

The report estimated the total cost of this improvement at $12.50 per acre, payable in installments scattered through twenty years, which expenditure will enhance the value of the land, at present market rates, $30 per acre and also allow the full use of a greatly augmented business profit for fifteen years of the twenty years. The works are described as simple but comprehensive in character, and well adapted to the popular needs.

In the report on the Perris district the location and surroundings are accurately described. The detail of the organization and the inclusion and exclusion of certain lands not originally included in its boundaries is set forth. The necessity of and adaptability of the land to irrigation is admitted.

In the present instance, it happens that the lands embraced within the district to be reported are not altogether unproductive without irrigation; indeed, considerable portions of them have been cultivated in cereals for seven or eight years. In the more favorable seasons these have produced good crops, and have so far paid as wheat-growing lands; their marketable value for this purpose has ranged from $10 to $20 per acre. Moreover, vines and deciduous fruit trees start well and while young thrive on these lands; they only fail later in life, when the fruiting function exhausts the available moisture of the soil. The plain on which this district lies falls short of being practically a fertile region because of one failing; and that is, the want of sufficient moisture at the right time to mature crops.

It is doubtful whether, by the very best appliances and most perfect system, wheat-raising ever could here be made to support in comfort even its sparse population. This southern country has been, and will again be subject to series of very dry years. The wheat-growing practice on the San Jacinto plains has not yet passed through these. It commenced since such seasons have been experienced. Anticipation and hope of irrigation, though, have kept a population along from year to year, and during the past year, when this hope seemed to be approaching realization, there has been a very noticeable incoming of people.

The supply of this district comes from the Bear Valley reservoir, and the following is a copy of the contract between the parties:

WATER RIGHT AND DELIVERY CONTRACT.

This agreement, made this 20th day of January, 1891, between the Perris Irrigation District of San Diego and San Bernardino counties, Cal., a corporation, the party of the first part, and the Bear Valley Irrigation Company, a corporation, having its principal place of business at Redlands, San Bernardino County, Cal., the party of the second part,

Witnesseth: That in consideration of the mutual covenants herein contained, the parties hereto agree as follows: The party of the second part hereby agrees to and does hereby sell to the party of the first part 16,000 of its class B acre water-right certificates, authorized by its board of directors by a resolution regularly passed on the 8th day of January, 1891, a copy of which resolution is hereto attached, marked Exhibit A, and made a part hereof, for the sum of $240,000 of the first irrigation bonds of said Perris district, bearing interest from January 1, 1891,* at 6 per cent per annum, payable semiannually on the 1st days of July and January; said 16,000 certificates to be delivered to the Perris Valley Bank at Perris, Cal., as soon as the same are lithographed and signed by the proper officers; to be held as collateral security for the payment of the irrigation bonds now authorized by said Perris Irrigation District, and including the said $240,000 in bonds to be paid for said 16,000 certificates, together with interest as the same matures.

The said party of the second part agrees to deliver to the party of the first part the water called for by said 16,000 certificates, as follows: The water called for by 800 of said certificates shal be delivered on the 1st day of April, 1891, as follows: The water called for by 266 of said certificates shall be delivered at the point marked A on the map of the Perris Valley, showing the boundaries of the Perris Irrigation District, hereto attached, and marked Exhibit 1, and made a part hereof; the water called for by 534 of said certificates shall be delivered at the point marked B on the said map marked Exhibit 1.

The water called for by 2,000 of said certificates shall be delivered on the 1st day of April, 1892, as follows: The water called for by 733 of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by 1,467 of said certificates shall be delivered at the point marked D on Exhibit 1.

The water called for by 2,000 of said certificates shall be delivered on the 1st day of April, 1893, as follows: The water called for by 666 of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by 1,334 of said certificates shall be delivered at the point marked D on said Exhibit 1.

The water called for by 2,000 of said certificates shall be delivered on the 1st day of April, 1894, as follows: The water called for by 666 of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by 1,334 of said certificates shall be delivered at the point marked D on said Exhibit 1.

The water called for by 2,000 of said certificates shall be delivered on the 1st day of April, 1895, as follows: The water called for by 666 of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by 1,334 of said certificates shall be delivered at the point marked D on said Exhibit 1.

The water called for by 7,000 of said certificates shall be delivered on or after the 1st day of April, 1896, and on or before the 1st day of April, 1899, as the directors of the said Perris District may hereafter determine, and at the point A the water called for by one-third of said certificates, and at the point D the water called for by two-thirds of said certificates.

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*This was subsequently changed to July 1, and the coupons for first six months' interest were cut and returned.

The party of the second part further agrees that it will sell to the party of the first part 4,000[*] more of its said class B acre water-right certificates for $60,000 of the first irrigation bonds of the said Perris Irrigation District, provided the said party of the first part shall elect to purchase said 4,000 additional certificates on or before the 1st day of July, 1891. Said 4,000 certificates to be delivered to the Perris Valley Bank, at Perris, Cal., as collateral security for the payment of the irrigation bonds now authorized by said district, and the interest as the same matures, and will deliver the water called for by said additional 4,000 certificates on or after April 1, 1896, and on or before April 1, 1899, as the directors of said Perris Irrigation District may hereafter determine; the water called for by one-third of said certificates shall be delivered at the point marked A on said Exhibit 1; the water called for by two-thirds of said certificates shall be delivered at the point marked D on said Exhibit 1.

The party of the second part further agrees that the sum provided to be paid on the 1st days of April and October in the said certificates shall commence as follows:

On 800 of said certificates on the 1st day of April, 1891; on 2,200 of said certificates on the 1st day of April, 1892; on 2,000 of said certificates on the 1st day of April, 1893; on 2,000 of said certificates on the 1st day of April, 1894; on 2,000 of said certificates on the 1st day of April, 1895; and the remainder of said certificates on the 1st day of April of each year, on the number of certificates represented by the water called for by the directors of said Perris Irrigation District, as hereinbefore specified between the 1st day of April, 1896, and the 1st day of April, 1899, and in any event the payment to commence on the balance of said certificates on the 1st day of April, 1899.

The party of the first part hereby agrees to pay the party of the second part the sums called for by said certificates as hereinbefore specified in accordance with the terms of the said certificates. A copy of said Class B acre water-right certificate is hereto attached, and marked Exhibit 2, and made a part hereof, and all the stipulations and agreements therein contained are hereby assented and agreed to by said party of the first part.

The party of the first part also agrees to pay the party of the second part $60,000 in its first irrigation bonds, for said additional 4,000 Class B acre water-right certificates, on or before the 1st day of July, if it shall elect to purchase said additional 4,000 certificates, and in the event of its purchase of said additional 4,000 certificates it will pay the sums called for on the 1st days of April and October on the number of certificates represented by the water called for by the directors of said district as hereinbefore provided.

And the party of the first part further agrees, that the said 16,000 Class B acre water-right certificates, and said additional 4,000 Class B acre water-right certificates, if the same shall be purchased as hereinbefore specified, shall be deposited with the Perris Valley Bank, Perris, Cal., as collateral security for the payment of the irrigation bonds now authorized by said district, together with the interest on the same as the same matures.

The party of the first part further agrees that the point of delivery of the water called for in the year 1891, at point marked B on said Exhibit 1, may after the year 1891 be changed to the point marked D on Exhibit 1. And the party of the first part also agrees that it will construct, at its own expense, a steel pipe from the point B to the point C, as shown on Exhibit 1, of capacity sufficient to carry 150 inches of water, and from the point C to the point D of a capacity sufficient to carry 100 inches of water, and that the party of the second part shall have the right to flow through said pipe from the point B to the point C 50 inches of water, and that after the water hereinbefore specified to be delivered at the point marked B shall have been changed in its delivery to the point marked D, the steel pipe hereinbefore agreed to be constructed by the party of the first part shall belong to and become the property of the party of the second part.

It is understood and agreed that a sufficient part of the water to be delivered at the point A shall be at an elevation to cover the elevated lands on the east side of the San Jacinto River in said district, taking the elevation of the NE. corner of Sec. 25, T. 4 S., R. 3 W. as the highest elevation at which water is to be delivered, and provided that the elevation at said point of delivery shall only be sufficient to meet the requirements of said elevated lands, the lower to take at lower elevations.

And it is further agreed, that if in the future the party of the second part desires to change the point of delivery of water for said elevated lands, it shall have the option so to do; providing it shall not cause the party of the first part any extra expense to take such water from such changed point of delivery.

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[*] There is a supplemental agreement of recent date on this point, referred to in the report.

It is understood and agreed that the elevation or pressure of the point D shall be 1,650 feet.

In witness whereof the parties hereto have caused this agreement to be executed in duplicate the day and year first above written, in pursuance of resolution, passed by their respective directors, authorizing the execution of this agreement.

[SEAL.]
PERRIS IRRIGATION DISTRICT,
J. W. NANCE, *President.*
H. A. PLIMPTON, *Secretary.*

[SEAL.]
BEAR VALLEY IRRIGATION COMPANY,
AMMON P. KITCHING, *Vice-President.*
FRED E. HOTCHKISS, *Secretary.*

The farming area available is reported at 21,300 acres; the total area of the district is 22,800 acres.

The district will receive its supply through two main lines following a high line on either side of the valley occupied. The west side has the only system under construction, and it will cost altogether $157,438. The complete works for the district, including a town service system and water right, will cost $710,000, and, deducting the discount on the sale of bonds, will require an issue of $750,000 in bonds. The value of the land before the district formation was only from $10 to $20 per acre. The present selling value of the bare land is $50 to $75, subject to district assessments; while in a short time the unplanted land will bring $100. The following table, compiled by the engineer for the purpose of making an estimate of the debt-paying ability of the district, will show whether or not the district system will pay as a commercial investment on the part of those who buy the land and make farms, orchards, homes, and towns thereon.

	Value when irrigation commences.	Value in ten years.	Value in twenty years.
Farming lands	$2,000,000	$4,000,000	$6,000,000
Improvements	100,000	1,000,000	2,000,000
Town property and improvements	150,000	500,000	1,000,000
Total	2,250,000	5,500,000	9,000,000

The total cost of the enterprise per acre of the entire district will be about $31.10, payable in instalments running over twenty years. A comparison of these figures with the well known cost of water rights from private corporations must, in the opinion of this office, successfully refute the charge that an administration of irrigation by the community of irrigators increases the cost of the work.

In the Alessandro district the report goes back to a consideration of the irrigation conducted therein by the Spanish Mission priests; and notes that in this tract the "waters of irrigation were community property from the start, and lands were apportioned to the settlers." The district lies in the San Jacinto Valley and practically resembles the Perris district in all physical features. The water supply of this district is also from the same source—the Bear Valley reservoir.

The Alessandro district is in the undisputed zone of irrigation in southern California, and there are no equally large areas of land materially better adpated in surface and soils to cultivations of high class and by irrigation methods suited thereto.

Its agreement for water with the Bear Valley Irrigation Company is similar to that of the Alessandro district with the same company. The contract provides for the purchase of (acre) water right certificates and the delivery of water as follows:

Time of commencement	Number of certificates.	Number of acres.	Number of cubic inches.
June 1, 1891	4,000	2,000	500
Apr. 1—			
1892	6,000	3,000	750
1893	6,000	3,000	750
1894	6,000	3,000	750
1895	6,000	3,000	750
1896	6,000	3,000	750
1897	6,000	3,000	750
1898	6,000	3,000	750
1899	5,000	2,500	625
Total	51,000	25,500	6,375

The Alessandro irrigation district is practically an adjunct of the Bear Valley Irrigation Company's business, and is an exponent of its prudence in dealing with present conditions. Attention is called to the fact that the very best private methods applied to the irrigation district system has made no material difference in the cost per acre of the works projected. Alessandro is bonded at $30 per acre. The engineer says:

> The Alessandro district bonds having been issued to the extent of $765,000 for water delivered (distribution works thrown in, as it were), there is, as security for the loan contemplated by the law, property now assessed on a valuation of $2,436,036; of which $2,396,819 is the rated value of the farming lands. In my opinion these lands are now actually worth $3,000,000 as a minimum safe valuation. The prospective values are as follows:

—	When irrigation well commences.	In ten years thereafter.	In twenty years.
Farming lands	$3,000,000	$6,000,000	$9,000,000
Improvements	150,000	1,500,000	3,000,000
Town property and improvements	200,000	600,000	1,200,000
Total	3,350,000	8,100,000	13,200,000

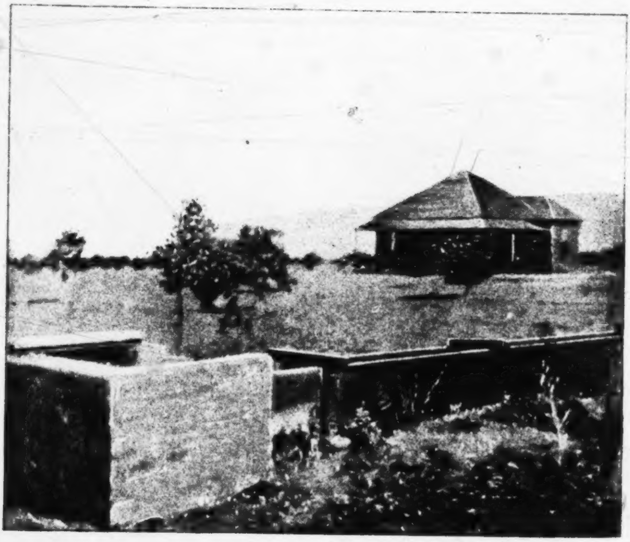
Continuing under the head of cost of irrigation, the report continues:

> If we assume, as is not unlikely to be the case, that main works for the full service, pro rata, of Alessandro district will cost the Bear Valley Irrigation Company as much as $17 per acre of the district area, the cost of this irrigation system, including the distributary works at $18 per acre, as already reported, when looked at merely from the engineering standpoint, will have been $35 per acre.

Taking lands worth certainly less than $20 per acre without water, and making them worth, immediately, really $150 per acre, works for the purpose might be regarded as cheap at much more than the above possible cost. The original land owner in this district will ultimately have paid for works and water rights, in purchase of land and in payment of bonds, $48 per acre, that is, $18 as part of land and cost, and $30 for water and delivery, interest not included.

There has been no litigation or adverse public sentiment in either the Perris or the Alessandro districts.

In closing this brief review of the work of Mr. Hall, it is only necessary to say that the figures presented are not always given in the same



CEMENT HYDRANT AND FLUME DISTRIBUTING WATER ON SMALL FRUIT FARM
REDLANDS, CALIFORNIA.

relation presented by the author, for the reason that our purpose in their use is to a great extent different. Mr. Hall's work, viewed as the verdict of a valuation expert, is extremely well done. The seperate district projects are always indorsed, but under the lens of his scrutiny a pale reflection of doubt seems to be cast on the enabling law or principle of the system. The following extract from the Alessandro report will illustrate this:

> No such complete and perfect works of distribution as those going into Alessandro district ever would have been attempted but for the unification of the speculative advantage to be gained by them. These works are put in to sell the lands at high figures, and they will do it, in fact are doing it. There was no division of opinion on the question of building them, no community to be consulted, no vote to be had. The speculative company builds them, and gives them to the district. The purchasers of land, the settlers, pay for them in advanced land prices. The better works enhance actual values much more than the cost difference over ordinary construction. And, moreover, system and economy of construction keep cost much below that probable under community management. The other large land owners take the cue. The improvement becomes complete in the district. A specially desirable and thrifty class of settlers is thus drawn in, and district success is assured.

The propositions laid down in this paragraph are, in the light of recent events at least, admissible of argument. The character of the works in the Turlock and Modesto districts are in their way as thorough and able as the constructions referred to by Mr. Hall. Indeed, if the great areas to be reclaimed are considered (more than 550,000 acres of land), they are less costly and more important in a beneficial sense.

In northern California the conditions affecting irrigation have been very complex. The provision in the appropriation act of October, 1889, which reserved all irrigable land from settlement, has exercised, it is claimed on all hands, a very prejudicial influence on progress in this region. Mr. C. C. Hutchinson, of Susanville, Lassen County, a well-known western pioneer, is fully acquainted with the conditions of irrigation and intimately identified with its progress. He made a special trip to Reno, Nev., to advise with the special agent in charge of the irrigation inquiry, and, in discussing the region under consideration, said:

> I have had a great deal of experience in the settlement of this western region, and these mountain valleys in northern California are unquestionably adaptable to a series of prosperous agricultural settlements. These valleys are backed by mountains covered with timber and full of mines, which, when opened, must attract favorable attention. It is a very healthy region. The climate, take the year together, is considerably more equable and agreeable than that of Indian Territory or Arkansas. The development of northern California and Nevada is simply a question of irrigation.
>
> The first effect of the act of October, 1889, was to retard all work that had been commenced in new irrigation enterprises, and especially in Lassen County (in which I am interested) east of the Sierra Nevada Mountains, and in all northeastern California. At the date of the passage of that act, water was already stored for the irrigation of 10,000 acres of land; but the effect of the law was to prevent purchasers from taking any of these Government lands, and our hands were thus tied for more than a year, until the relief given by the Fifty-first Congress, when parties immediately began to come in from Illinois, Wisconsin, and Iowa, and take these desert lands. This United States survey proposed for irrigation purposes could have designated and reserved storage sites, and indicated the proper methods of canal distribution, without having to withhold from settlement all the lands that could be irrigated. If the power of reservation had been applied to the lands that could not be irrigated, or were above the reach of ditch water, it would have been sensible, for that would have afforded permanent water sheds for the irrigable areas, and would have also included the reservoir sites.
>
> This whole Sierra region is full of natural reservoir sites adjacent to, but separate and distinct from, the streams themselves. The proper position for a reservoir is not across the mouth of the natural stream bed, but in basins that may be fed by the stream without building a dam across its flow. A large amount of the dirt placed in dams has been washed out because of the unsafe method of making reservoirs in the beds of these mountain streams.
>
> Lassen and Modoc counties have an area of reclaimable land of about 1,000,000 acres, which is a conservative estimate. In general terms this land will produce

anything that can be grown in the northern half of the United States. We have mild winters, and there never has been a tree injured by winter cold, although we have had some killed by early or late frost.

The oldest irrigation enterprise in Lassen County is that known as the "Eagle Lake Land and Irrigation Company." The body of water which it is proposed to tap by means of a tunnel covers a surface area of 2,800 acres. It will give in depth an irrigation supply of three acre feet, and is an engineering proposition of perfect feasibility, provided the capital is available to construct the tunnel. During the past fall considerable activity has been shown and the company report the work well under way. Considerable rivalry exists between the Lassen projects, but they are all worthy of consideration. Accusations relative to dealings with desert-land entries circulate freely, but this office was not charged with an inquiry into such matter. The hydraulic projects as designed to serve reclamation purposes are within its province and among these that of Eagle Lake, Lassen County, is worthy of consideration.

The Honey Lake Valley Land and Water Company, of which Mr. Grunsky is consulting engineer, is interested also in reclamation within this County. It proposes to impound water to irrigate the land lying to the east of Honey Lake, by means of a dam in Long Valley of the following dimensions:

	Feet.		Feet.
Extreme height	96	Length of base, about	200
Width of base, about	500	Length at height of 85 feet	740
Width of top, about	20	Length at height of 96 feet	950

This will raise the water to a height of 90 feet above the present bed of the stream, or within 6 feet of the crest of the dam, and the water surface of the reservoir will have an area of about 1,081 acres with an average depth above the outlet gates of 30.4 feet, thus giving an available capacity in round numbers of 1,431,164,000 cubic feet, or 10,733,700,000 gallons, being about 100,000,000 cubic feet greater than that of the Bear Valley reservoir, in San Bernardino County, and nearly twice that of the Sweet Water, in San Diego County, two of the principal irrigation reservoirs in the country.

The three reservoirs in this region are at a general altitude of 4,100 feet. Observations of the evaporation from the Honey Lake reservoir during last July was 2 inches over the surface of the lake. Taking the experience of the Bear Valley people as a guide, it may safely be asserted that the loss by evaporation in this region will be compensated by the natural inflow of the summer.

The estimated duty of water for this reservoir is 1 cubic foot per second for 300 acres during the irrigation season of one hundred days.

The consulting engineer, Mr. Grunsky, whose experience and knowledge on this question is the result of almost exceptional opportunities of study, supports these opinions by the following statistics:

Redlands, San Bernardino County, uses 1 inch to 6 acres.
Rialto, San Bernardino County, uses 1 inch to 7 acres.
Etiwanda, San Bernardino County, uses 1 inch to 8 acres.
Cucamongo, San Bernardino County, uses from 1 inch to 8 to 1 inch to 10 acres.
Ontario, San Bernardino County, uses 1 inch to 10 acres.
Pomona, Los Angeles County, uses 1 inch to 10 acres.
Santa Ana, Orange County, uses 1 inch to 16 acres.
San Diego Land and Town Company (Sweetwater), San Diego County, uses 1 inch to 10 acres.
On the Ganges Canal, India, 1 inch to 6.6 acres is used.
On the Jumna Canal, India, from 1 inch to 5.5 to 1 inch to 6.1 acres is used.
At Valencia, Spain, 1 inch to 6.5 acres is used.

The consulting engineer estimates the cost of these works as follows:

Dam, 428,500 cubic yards earth, at 12½ cents		$53,562
Excavation for foundation, trench, 30,000 yards, at 12½ cents		3,750
Outlet works—		
Brick, 255 M, per M at	$5.00	
Cement per M at	5.00	
Lime per M at	2.00	
Mason per M at	5.00	
Helpers per M at	1.00	
Board per M at	1.00	
	19.00	4,845
Gates and placing same		1,000
Waste-way and drop to creek		1,450
		64,607
Canals and ditches:		
2½ miles, 10 feet bottom, 4½ feet water at $2,750		$6,875
8 miles, 12 feet bottom, 3 feet water at $400		3,200
2 miles, 10 feet bottom, 3 feet water at $325		650
11½ miles, 10 feet bottom, 2 feet water at $220		2,530
28 miles, 7 feet bottom, 2 feet water at $160		4,480
57 miles, 4 feet bottom, 1 foot 9 inches water at $55		3,135
		20,870
100 feet flume at $2		2,000
		22,870
Tools, buildings, etc		12,075
		99,552
Temporary wasteway, 80 to 100 M feet lumber	2,000	
Incidentals	5,000	
		7,000
		106,552
Deduct value of plant		5,000
Total cost of works		101,552

The above estimate contemplates the purchase by the company of all teams, machinery, etc., that will be required in constructing the dam, which will prove the most economical method, insomuch as it calls for a smaller outlay than would be necessary in the event of hiring teams, and when the work is completed there will be left on hand a working plant.

The soil is a dark sandy loam of great depth and richness and retains moisture well. When irrigated it produces apples, pears, prunes, plums, currants, in fact, all the hardier fruits in great abundance and of superior quality. All kinds of vegetables, hops, corn, alfalfa, and nearly all forage plants do well and yield heavily. Among the fruits, the apples attain special excellence, and command the highest market prices.

In Lassen County a duty of 1 inch to 5, 8, and in one instance as high as 11 acres has been attained.

The proof by practice of this high duty of water will greatly simplify irrigation conditions in northern California.

Irrigation by means of stored water is always a very costly method, but if the able engineers who are in charge of this project demonstrate that 1 cubic second foot of water will irrigate 300 acres of ordinary farm land under favorable conditions it will bring stored water within the purchase of the farmer who depends for his subsistence on the growth of the less remunerative crops, such as are expected to be raised in this region. The three projects now under way in Lassen County expect to deal principally with irrigation districts and are so shaping their administrative policy.

The three storage companies operating in Lassen County propose to deal directly with irrigation districts in the disposition of their water.

The royalty cost of water under the Eagle Lake plan will be $5 per acre; the annual cost about $1 per acre.

The growth of irrigation is further illustrated by the efforts of private parties to control the Chowchilla River. Water is now being impounded to irrigate about 40,000 acres on the Sharon estate. A dam 100 feet high, of uncoursed rubble masonry, 780 feet on the crest and 68 feet on the base of the upstream arch type, of radius at the center of 1,146 feet, gradually diminishing to 736 at the abutments, thus broadening the base on which it abuts against the hillsides, is thrown across the river at a favorable point in the cañon. Wasteways on either side of the dam of 15,000 second feet combined discharge are provided. It has a uniform batter of 1 in 25 feet below the first 10 feet. The crest, without counting the parapet, is 10 feet thick. Two outlets, excavated on either side of the dam in the solid rock, 20 feet above the base, in which steel pipes will be laid in cement, are provided; and in addition to these there will be another sluice laid 10 feet deep, in rock 6 feet above the bottom of the dam, in which a steel pipe will also be laid in cement. At an elevation of 420 feet above sea level 42,000 acre feet will be stored. The flood discharge of the Chowchilla is 1,500 second feet. The stream bed is used as a canal for 2½ miles, and water is diverted to the irrigation ditch 3½ miles long and of 300 second feet capacity by a weir overflow dam into a natural depression in a ledge of rock, which will be used as a part of the canal. This diversion weir is of masonry, 12 feet in maximum height and 400 feet along the crest. It is the purpose of the Sharon estate to hold the 42,000 acres irrigated in one ranch.

The Folsom Dam, built by the State of California by the use of convict labor, having been in process of construction for several years, was completed within the past year. It is a solid granite structure, 92 feet high, 65 feet thick at base and 20 feet at top, provided with a movable shutter or weir on top 6 feet high, to be raised by powerful hydraulic jacks operated by water power. The stone was quarried from the banks. Mr. Humbert was the engineer. The dam was constructed principally to develop water power for the penitentiary, but it having been shown that 500,000 acres of land may be irrigated from this source, the structure will probably find its most profitable use as a diversion weir to water the adjacent lands.

The Gage system of artesian wells and canals at Riverside has been referred to in former reports. A new system known as the Whittier ditch, modeled on the Gage plan, has been started near Whittier, 14 miles from Los Angeles. The conduit is 10 miles long, partly lined with cement and partly a covered wooden flume. Its construction is somewhat unique, and the supply is purely artesian, located in the upper San Gabriel Valley and near the foothills. The supply comes from very irregular strata, mostly sand and gravel, but no rock has been found by any of the drills. The first well sunk showed the following stratum:

Irrigated Kitchen Garden and Orchard at Tulare, California.

	Feet.		Feet.
Sand to	10	Clay to	118
Coarse gravel to	20	Gravel to	120
Clay to	23	Clay to	121
Sand to	53	Sand and gravel to	128
Clay to	56	Clay to	131
Gravel to	100	Sand and gravel to	168
Clay to	110½	Clay to	179
Coarse gravel to	116½	Sand and gravel to	200

This is the deepest boring. Although these wells are sunk within 100 feet of each other, no two wells show the same strata. There are fourteen in all, with 7-inch bores. The pressure has not been measured, but a flow of 3 inches above the pipe from all is steady and constant. In utilizing this water the pipe is brought up into a closed box casing, and from there emptied into a closed wooden ditch which conducts the water to the cement ditches for distribution. At the date of examination no system of distribution had been provided, for the company was engaged in developing their water supply. It may be generally assumed that this system can be developed throughout the San Gabriel Valley and in valleys of similar local conditions. Already 400 miners' inches of water have been obtained, and it is expected that 1,000 inches of water will be ready for irrigation next year.

The great value of water in southern California, while it has made storage possible with profit to the irrigator, has also stimulated a close inquiry into the extent and capacity of the phreatic supply that may be developed from the cienegas, the lost flows of streams, or the underflow of others, and from shallow drainage under pressure or deeper artesian sources. Besides the wells at Whittier the engineer of this scheme is running a drift tunnel into the bed rock, and is meeting with such success as to promise ample reward. The land to be irrigated by this water has heretofore been range land for cattle and sheep.

ANSWERS FROM CORRESPONDENTS.

The following summaries are made from replies received to circulars sent by this office:

FRESNO COUNTY.

Firebaugh (post-office), J. W. Schmitz (October, 1891):

Water supply: For Poso Farm, from "San Joaquin and Kings River Canal and Irrigation Co.;" for Eastside (Chowchilla and Riverside canals), San Joaquin River.
Works: Poso ditch, 16 feet on bottom, 20 feet on top; Chowchilla canal, 25 feet on bottom, 34 feet on top; Riverside Canal, 30 feet on bottom, 39 feet on top. Head gates, Poso Farm, 1; Eastside, 3.
Cost per mile: Poso Canal, $400; Chowchilla, $2,440; Riverside, $800.
Average yield per acre: Alfalfa, 6 tons; grain, 15 bushels.
Average cost per acre for annual maintenance and repairs, $1.
Average cost per acre for preparing land for cultivation under irrigation: For grain, $8; for alfalfa, $7.50; for grass land, $2.
Area under ditch: Poso Farm, 4,800 acres; Eastside, 10,500 acres.
Area under cultivation: Poso Farm, 4,200 acres (one-sixth in grain, balance alfalfa); Eastside, 4,500 acres (200 acres in grain, balance in alfalfa).

Fresno (post-office), J. S. Dove (October 16, 1891):

Has 140 acres under cultivation. Water supply, from a canal company that obtains its supply from Kings River.
Cost of water supply per acre, 62½ cents.
Cost per acre for preparing land for cultivation under irrigation: "Some of the lands, not level or smooth, cost from $10 to $20 per acre to prepare for irrigation."
Chief products under irrigation: Raisin and wine grapes, oranges, apricots, peaches, pears, etc.; alfalfa.
Value of product per acre: "Sold his raisin grapes on the vines for $18 per ton—netted $700 per acre (3-year old vines); alfalfa (within 5 miles of town), $40 to $50 per acre. Six crops cut in the season by some of his neighbors."

Fresno (post-office), Wm. McWhorter, secretary, "Sunset Irrigation District."

Water supply: Kings River, "supply 5,000 cubic feet from April 1 to June 1."
Works: Main canal 110 miles proposed (works not yet constructed).
Estimated cost (section 1), 13 miles, $850,000; (section 2) 50 miles, $100,000; (section 3) 47 miles $47,000.
Area to be covered: 360,000 acres.
Interest on bonds and current expenses this year: 3 mills per cent.

Fresno (post-office), J. C. Shepherd (September, 11, 1891):

Fowler switch canal: Source of supply, Kings River; supply from January to August; river runs low in August, and other canals have prior rights.
Works: 30 miles main canal; 40 feet on bottom, 80 feet on top, 5 feet deep; two head gates; one waste gate; no reservoirs.
Area under ditch: 250,000 acres (portion of same land may be also covered by other ditches).
Cost per mile: $5,500.
Average cost per acre of irrigation works: Ditches, etc., $5.
Average cost per acre for preparing land for cultivation under irrigation, $12.50.
Average cost per acre for annual maintenance and repairs, 25 cents.
Staple products under irrigation: Apricots, peaches, grapes, and alfalfa.
Average value of product per acre: Fruit, $75; alfalfa, $50 (vines have not yet reached full bearing.)

Madera (post-office), Thomas E. Hughes (October, 1891):

"Madera Canal and Irrigation Company;"—water supply, Fresno River, and a branch of San Joaquin River turned into it. Canal taken out after river reaches the plain or level lands.
Works: 100 miles canals; 30 to 40 feet on bottom; 50 to 75 feet on top. One dam in mountains on branch of San Joaquin River; and one brush dam at head of canal; 150 to 200 distributing head gates throughout the system. One reservoir contemplated.
Area under ditch: 20,000 acres (under system at present); under cultivation, 13,000 acres.
Cost per mile: $50 to $100 (after reaching the plains). Estimated cost of reservoir, about $100,000.
Cost of water supply to user per acre, $1. Annual rental cost, $1.
Average cost per acre for preparing land for cultivation under irrigation: About two-thirds of the land between San Joaquin and Kings rivers cost from $2.50 to $10; one-third, from $10 to $30 to prepare for irrigation.
Cost per acre for annual maintenance and repairs: About $100 for 640 acres.
Estimated value of product per acre: Raisin grapes, $50 to $200; alfalfa, $50 to $100 (grain on same land, $10 to $25); tree fruits, $50 to $200.

["It is estimated that in Fresno County between the San Joaquin and Kings rivers, 575,000 acres are now irrigated or are affected by irrigation. About 75,000 acres of land, mainly in grapes, fruit, and alfalfa has, for the last four to six years, needed no surface irrigation on account of the lands having been sufficiently subirrigated by the general seepage from the canals. Twelve years ago surface water could be found only at a depth of 50 to 60 feet; it is found now at a depth of 4 to 7 feet."]

KERN COUNTY.

Bakersfield (post-office), J. W. Thompson (October, 1891); has 40 acres under irrigation.

Water supply through Calloway Canal from Kern River; water brought by a lateral ditch 5 miles long, 20 feet wide; head gates of ditch, 3 (one at canal head of ditch, two on farm).
Cost per mile of lateral ditch, $500.
Cost of water supply to user per acre, $1.50.
Average cost per acre of irrigation works: Ditches, $2.50.
Average cost per acre for annual maintenance and repairs, 10 cents.
Average cost per acre for preparing land for cultivation under irrigation, $3.
Staple products under irrigation: Raisins, peaches, pears, prunes, plums, apricots, nectarines, figs, etc.; alfalfa, hay, live stock, barley, wheat, potatoes, and garden vegetables of all kinds.
Estimated value of annual product per acre, $100.
Area under Calloway Canal, 200,000 acres; under cultivation, 45,000 acres.

In reply to circulars and other sources, the following general data, relative to this county, have been compiled:

Works—During 1891 about 100 miles of canals have been constructed. Over 1,000 miles were previously in operation. The new canals are large and important. The Kern Valley Water Company's canal is 125 feet wide at top and 22 miles in length. It carries 6,000 cubic feet of water per second. The Kern and Tulare irrigation district have made surveys for a new canal to irrigate 150,000 acres of land. The "78" Canal Company, just incorporated, will build, during 1892, a canal to irrigate 150,000 acres, known as the "Weed Patch," at a cost of $750,000.

Of new land 3,000 acres were set out during 1891, to fruit trees and grape vines.

LASSEN COUNTY.

E. R. Dodge, a director of "Eagle Lake Land and Irrigation Co." (September, 1891); reports work in progress on a cut into Eagle Lake (2,800 acres), which will give 3 acre feet for irrigation purposes:

Estimated cost of water supply to user per acre, $5; annual rental cost, $1.

LOS ANGELES COUNTY.

Azusa (post-office), W. R. Powell (October 1891):

Local water supply (1st) San Gabriel River, ($\frac{308}{170}$ of the first 1,700 inches of the river-water surplus goes to other systems); (2d) a mountain stream.

Works: Loose dam made yearly; 900-foot tunnel; open ditch to carry 1,000 inches; about 150 gates.

Area under ditch, 4,000 acres; under cultivation 3,000 acres.

Average cost per acre for first-class works in locality, $15.

Average cost per acre for annual maintenance and repairs, $1 (to include pay for water tender).

Products: Oranges, lemons, strawberries, etc.; alfafa, potatoes, etc.

Average value of product per acre, $50 to $700.

Downey (post-office), T. J. Kerns (October 3, 1891):

Average cost per acre in his neighborhood, for preparing land for cultivation under irrigation: Plowing, $2; harrowing, 50 cents (soil is a rich, sandy loam, easily cultivated).

Cost per acre for irrigation works, ditches, etc.: About $1 in the immediate vicinity; on the mesa and foothills is more, in some places reaching $20. The ditches generally are easily constructed.

Average cost per acre for annual maintenance and repairs: 20 to 25 cents per acre will clean ditches twice yearly.

Products under irrigation: Corn, barley, alfalfa, sugar cane, sugar beets, sweet and Irish potatoes, and all vegetables, oranges, lemons, figs, and all deciduous fruits, English walnuts, etc.

Average yield and value of same: Alfalfa, cut 6 times yearly, 1 to 2 tons per acre each cutting; sells in the shock at $7 per ton; corn, 45 to 100 bushels, selling at $1.45 per 100 pounds.

Los Angeles (post-office), J. W. Potts (October 3, 1891):

Water supply, Los Angeles River: Area irrigated from it about 15,000 acres; flow of river in the fall (before the winter rains) about 75 cubic feet per second. Water and works (including 2 reservoirs) owned by city; cost of works, about $30 per acre for lands irrigated; water sold at $2.50 per day for a "head" of 100 miner's inches; general duty of water, 1 miner's inch for 10 acres (steady flow). Estimated irrigable capacity of river, if winter supply was properly stored in reservoirs, 150,000 acres.

Average cost per acre for preparing land for cultivation under irrigation (plowing, etc.), $2.50.

Staple products under irrigation: Oranges, lemons, grapes, peaches, pears, etc. (everything suitable to the climate).

[Corn is generally raised in the wet lands supplied by underground seepage; wheat and barley by means of winter rains; fruits do well on the foothills without irrigation.]

Average value of products per acre: Oranges, $500 to $1,000; lemons, $1,000 to $1,500; peaches, pears, apples, $200 to $500; (two or three crops of different products are raised yearly.)

Los Angeles (post-office), F. A. Atwater (October, 1891): Farm at Clearwater on "California Coöperative Tract."

Two years ago had from 2,500 to 3,000 acres under ditch; 1,000 acres cultivated by means of 3 to 4 miles of ditch, 4 feet on bottom; 10 to 15 feet on top; supplied from New River; course of river has changed and ditch of no use.

Only irrigation in that locality now by means of fifteen or twenty artesian wells, from 140 to 350 feet deep, costing from $150 to $500 each; about 300 acres irrigated.

Cost per mile for preparing land for cultivation under irrigation, $2.50 to $3.

Staple products under irrigation: Corn, potatoes, onions, and alfalfa.
Estimated value of product per acre, $20.

Pasadena (post-office), M. H. Weight (October 3, 1891):

City of Pasadena and adjoining lands directly tributary to it, comprise about 14,000 acres; about 7,000 acres in orchard and vineyard; city about 2 miles square, 1,600 acres of which is in orange, lemon, and deciduous fruit trees.

Water supply: Springs about 3 miles north of city in Sierra Madre Mountains; by means of iron pipe lines, to cemented reservoirs, thence distributed through same kind of pipe, ranging in diameter from 1 to 10 inches.

Capacity of springs: They furnish at present not less than 350 miner's inches per second, continuous flow; a much larger supply is being developed by means of tunneling and by constructing a submerged dam to utilize the large supply of water from the springs which now sinks into the sands; new system of reservoirs contemplated.

The pipe lines are being continually improved, extended, and enlarged.

C. H. Richardson, C. C. Thompson, T. S. C. Lowe, among others of Pasadena, testify as to—

Acreage in fruit in Pasadena proper, South Pasadena, and adjacent foothills, about 8 square miles, or 5,100 acres. Of this area 1,600 are planted to orange trees (budded), over five years old; 800 acres are in seedlings and about 150 acres are in bearing trees less than five years old, making in all for oranges at least 2,500 acres. In deciduous fruit trees there are 1,600 acres, 12 acres in walnuts, 20 in olives, and an acreage sufficient for 1,000 lemon trees. All are irrigated.

Product and value in oranges from $200 to $400 net per acre in 1891. On a 50-acre orchard adjacent to Pasadena the net profit in green fruit for last season was $9,000, or $180 per acre. Dried fruit would have made larger returns.

San Gabriel (post-office), A. Scott Chapman (October 5, 1891):

Water supply: Artesian wells; area irrigated, 150 acres.

Well, 400 feet deep; dirt reservoir, 8 feet deep, 120 feet diameter.

Cost of well and reservoir, $1,500; cost of reservoir, $215. Will supply 60 acres ($25 per acre).

Cost per acre for preparing land for cultivation, $10 (clearing land of brush). Total cost per acre for well, reservoir, etc., and preparing land, $35.

Staple products under irrigation: Oranges, lemons, walnuts, vegetables.

Average yield per acre: Oranges, 400 boxes; walnuts, 4,000 pounds.

Whittier (post-office), A. L. Reed (September, 1891):

Water supply: Artesian wells and springs; 14 artesian wells, 80 to 200 feet deep, develop 4½ cubic feet per second; springs develop 3½ cubic feet per second.

Works (not yet completed): 11 miles main conduit (cement and concrete); bottom width for 9 miles, 4 feet; top, 6 feet; depth, 3 feet 4 inches; for 2 miles, bottom width 3 feet 4 inches, same depth. Head gates, 1 set (of 2); waste gates, 2; wastegates with sand boxes, 2. Flumes, 6,200 feet (wooden, on piles and trestle).

System not yet in working order.

MERCED COUNTY.

[Data for this county, compiled from various sources in answer to circulars, is especially interesting in its bearing upon the organization of fruit-growing colonies. There are now fifteen in the county, and the briefed particulars are as follows:]

Name.	Area of colony.	Area planted.	Name.	Area of colony.	Area planted.
	Acres.	*Acres.*		*Acres.*	*Acres.*
Archer	320	80	Livingston	320	110
Ashe	900	....	Mitchell	280	120
British	5,840	100	Rialto	320	....
Bubach	1,280	510	Rotterdam	3,190	1,500
Deane	6,020	320	Towne	960	70
Dos Palos	6,000	6,000	Yosemite	640	200
El Capitan	1,920	185			
Honitos	210	25	Total	22,200	9,280

Nearly all of the planted area reported is laid down in fruit—almonds, apricots, berries, nuts, olives, peaches, pears, plums, prunes, and raisin grapes. In addition to the foregoing about 1,400 other acres have been planted in fruits.

The Merced Canal and Irrigation Company represent $3,000,000 of capitalization. The main canal is 50 miles in length; principal source of supply is the Merced River. The canal carries 4,000 cubic feet per second. There are two tunnels on route, with a total length of 8,500 feet. An open reservoir is known as Lake Yosemite. Its cost has been $2,000,000. The chief source of supply is the Merced River, fed by mountain snows.

J. L. Dickinson, of Los Banos:

Water supply from San Joaquin and Kings River.

Canals of large size, parallel to each other, 50 to 70 miles in length. Farms and orchards supplied by small distributories from main ditches.

Cost to user, $2.50 per acre; preparation of land, from $2 to $5; for irrigation, from $1 to $2; annual rates, not to exceed 15 cents per acre.

ORANGE COUNTY.

E. E. Edwards, Orange (post-office), September 22, 1891:

Water supply: Santa Ana River; flow sufficient for 36,000 acres.

Works: Open ditches and flumes; main ditch supplying neighborhood, 20 to 26 feet on top, 10 to 14 feet on bottom; in all, 123 miles of ditches, etc. Three head gates; built in 1877.

Artesian wells: 250 flowing in county, used for domestic and stock purposes. Use for irrigation just beginning in some neighborhoods.

Cost of main ditch from $800 to $7,000 per mile; average cost per acre, $17.50; annual cost to use for same, $6.60; cost per acre of repairs, etc., 50 cents.

Acreage served: Under ditch, 36,000 acres; under cultivation, 30,000.

PLACER COUNTY.

Jonas J. Morrison, Loomis:

Water supply is from South Yuba and Bear rivers, fed in the Sierra Nevada by snow and mountain springs. This is a foothills region, and all is under ditch. Our ditch (the South Yuba) carries 2,000 miner's inches, and usually fails us in July and August because the ditch is not large enough; supply is sufficient if latter was remedied.

Cost: We purchase from owner of main ditch at rate of 45 cents per miner's inch per annum. A miner's inch irrigates, with us, according to soils, from 5 to 10 acres. Annual maintenance is $1 per acre.

Cost of clearing land is about (for general farming) $20 per acre; for orchard clearing, trees, and planting.

Area: In this section 10,000 acres are under ditch; 4,000 under cultivation.

Products: Chiefly all varieties of deciduous fruits.

SACRAMENTO COUNTY.

Secretary of Natoma Water and Mining Company, Folsom (post-office):

Water supply is south fork of American River.

Works are a canal with capacity of 42 cubic feet per second, 17 miles of main, and 25 of small or lateral ditches.

Cost of per mile from $200 to $500. Cost of preparing land for cultivation, $5 to $50 per acre; the same for irrigation works per acre; of annual repairs and maintenance, from $2 to $10. Charge to consumer (royalty), $5 per acre.

Acres under ditch, 20,000; under cultivation, 1,200 acres.

Products: Table and wine grape, deciduous fruits, and vegetables.

SAN BENITO COUNTY.

George T. Elliott, Hollister (October, 1891):

Water supply: San Benito River and artesian wells; latter unlimited in supply.

Works: 50 miles of ditches, besides wells, reservoir of 30 acres; dam 120 feet long, 10 feet high; 50 head gates. Two systems in use, 10 miles apart. Cost of main ditch, $1,000 per mile; reservoir, $5,000; of wells from $150 to $1,000 each.

Acreage served: Under ditch, 10,000; under cultivation, 3,000 acres.

Cost of irrigation, $5 per acre; annual rental, $4 per acre; cost of repair, $1.

SAN BERNARDINO COUNTY.

[Data from several sources give the horticultural growth for the past year.]

There were planted of citrus trees, 9,454; of deciduous, 3,274; of vines, 2,808; a total of 15,486. The largest number planted by any one colony or settlement was at Riverside, 4,000 citrus trees. Redlands planted 1,200 of such trees, and 150 deciduous. At Alessandro, the new settlement under Bear Valley service, there were 1,100 citrus and 1,000 deciduous trees, with 100, vines planted. Highland, Ontario, and South Riverside were next in extent of planting. The fruit acreage of the county is reported at 41,440, an increase for one year's planting of 20,437 acres, or nearly as much as was previously cultivated for fruit. The division is as follows:

	Acres.		Acres.
Orange	22,871	Apple	250
Lemon	1,800	Olive	240
Peach	3,874	Nuts	250
Apricot	2,000	Vines	8,688
Pear	577		
Prune	550	Total	41,440
Fig	340		

F. C. Finkle, C. E., San Bernardino, states cost of preparing citrus orchard land at from $100 to $200; for other trees and vines, $50; for alfalfa, $10 per acre. Cost of irrigation works, from $10 to $20 per acre. Production is stated: Oranges and lemons, 300 boxes; deciduous fruits, 5 tons; raisins, 100 boxes; alfalfa, 4 tons per acre.

Robinson J. Jones, San Bernardino (post-office), September 24, 1891:

Water supply at Etiwanda is from two cañon streams, averaging 287½ miner's inches. It has been as high as 502 inches.

Works consists of two flumes, connecting with and discharging into reservoir. Ten miles of fluming. Reservoir 20 feet cement box, fitted with eight distributing lines. Timber dams in cañons divert water into flumes. Concrete pipes, with standpipes at every 10 acres, are used for distributing supply. Pressure is gained by a 10-foot fall in each 660 feet.

Acreage served and under cultivation, 1,100 acres.

Cost of water per annum to users, 75 cents per acre. Estimated cost of main irrigation works, $10 per acre. Orchard service borne by farmer.

Products: Fruits and vegetables, chiefly oranges, raisins, and lemons. Average return per acre, $125.

Solomon Neumann, Messina (post-office), (September 25, 1891), Highland, and East Highland:

Cost of preparation has been $75 per acre. West Highland cost is not over $20 per acre. These areas form what is known locally as the Highland district.

Cost of works, about $100 per acre; annual cost, about 75 cents for same to user.

Acreage: Under ditch, 6,000; under cultivation, 2,000 acres.

Products: Fruits, the profits of which per acre will be from $800 to $100, according to varieties and age of trees.

E. M. Hatch and H. H. Morgan (the latter is president of San Antonio Water Company), Ontario (post-office), September, 1891:

Water supply: San Antonio Canon, creek and tunnel.

Works and their character: Tunnel half a mile and cement ditch one-half mile in length; 62 miles of cement piping underground; one head gate; main pipe, 3 feet in diameter. Pipes cost for laterals about $1,200 per mile.

Cost: Preparing land about $20 per acre (Mr. Hatch says from $20 to $100); cement ditch for 10 acres, Mr. Hatch states, will cost $175. Cost of water per acre is not less than $100; annual cost to user about 75 cents per acre.

Acreage served: Under water, 4,500; under cultivation, 3,000 acres.

Messrs. Theodore C. Clark (general manager Bear Valley Company), F. G. Ferand, H. W. Allen, H. H. Sinclair (secretary South Fork Ditch Company), T. L. Lyon, C. J. Monson, and E. G. Judson write from Redlands (September and October, 1891):

Water supply: Santa Ana River and Bear Valley reservoir.

Area served: Under Crofton system, 3,000 acres under ditch and 1,800 under cultivation. Under all systems, served by Bear Valley, etc.: Under ditch about 18,000 acres, under cultivation about 13,000; contracts, when all are served, will bring 34,000 acres under ditch. Several other districts are served by the same system.

Cost of preparing land, from $10 to $40—latter for fruit; some rate cost as high as $50.

Cost of irrigation is variously estimated at from $15 to $40 per acre; probably $30 will be a fair estimate; annual rental is from $1.50 to $6 per acre; water royalty is rated from $30 to $75 per acre.

Return per acre averages: Deciduous fruits, $125 per acre; oranges, according to age of trees, from $100 to $800 net; alfalfa, 6 to 10 per year, $8 per ton.

A. E. Sterling, Redland (post-office), for Palm Valley Water Company (September 24, 1891):

Water supply: Whitewater and reservoir.
Cost of works: Main stone ditch of 10 miles, $14 per acre; private ditch (stone) or lateral flumes, $12 per acre.
Annual cost, about $1 per acre.
Area served: Under works, 3,000 acres, reclaimed from upper part of Colorado desert; under cultivation, 500 acres.
Products: All early fruits and fine vegetables, oranges, figs, grapes, dates, etc., all do well. All mature very early.

W. A. Coyrell, secretary Riverside Water Company (September 26, 1891):

Water supply: Santa Ana River, Warm Creek, and artesian wells; 80 cubic feet per second.
Cost of preparing for cultivation, land being level, $20 per acre.
Cost of irrigation: Works and water rights, $60 per acre; annual maintenance, $6 per acre.
Works, nature of: 40 miles of flume; 9 miles canal; 100 miles of lateral ditches, flume, stone and iron pipes; three head gates; two tunnels 3,380 feet long, 8 feet wide, 6 feet high; 10,400 feet of flume, 4 feet deep, 8 feet wide.
Cost of works: Main canal, from $1,000 to $10,000 per mile; of tunnels, $5 per lineal foot. In all other estimates make total cost $750,000.
Under ditch, 12,000 acres; under cultivation, about 7,000.
Annual product per acre (estimated): For citrus fruits, $500; for raisins, $100; for alfalfa, $20 per acre.
Products: All semi-tropical fruits, grain, alfalfa, fine vegetables.

George Dole, Riverside, (September 25, 1891):

Area under ditch, 17,675; under cultivation, 8,000 acres.
Cost of preparation and water for cultivation, $50 per acre.

A. H. Naftzger (president East Riverside Water Company), Riverside (post-office), F. C. Finkle, C. E., San Bernardino (post-office):

Water supply: Chiefly artesian wells, sufficient for 10,000 acres; present supply, 6 cubic feet per second.
Cost of preparing land, $25 per acre.
Cost of water, $75 per acre; annual rental, $2 per acre.
Works, nature of: Iron pipe line, 24 inch; 27 head gates; 16 miles of ditches; 3 of main ditch; pipe line cost $12,000; ditch, $2,000 per mile.
Under ditch, 3,000 acres; under cultivation, 500 acres.
Products: Oranges and lemons; trees not yet bearing.

The Riverside Water Company has 24,000 shares, at a par value of $10, or an original capitalization of $240,000. Each landowner in the 10,000 acres to be served took two shares at the time of organization, balance being held for purchasers of unimproved land. When fully sold each acre will be represented by two shares, transferable only with the land. The users are thus at all times the owners of the works. Each irrigator is entitled to all the water he needs, the regular rates, therefore, being fixed by the board of city trustees. The courts have sustained the issue of stock to unimproved land. Cost of works is reported at $900,000; cost per annum, $6 per acre. Artesian water under pressure is supplied for domestic purposes.

The Gage system, for the supply of Arlington Heights and other additions to the original Riverside, consists of 12,000 acres in two equal tracts, served by 38 artesian wells, whose supply is derived from the underflow of the upper Santa Ana River. These wells are sunk to various depths of from 150 to 500 feet. The water flows into the Santa Ana River, and thence through a canal, which is filled by a diverting dam. There are three other land companies which have constructed reservoirs and pipe systems, at a cost of $100,000. The Gage works and lands have been sold for $1,000,000 to a company.

Acreage "under water" in the valley of which Riverside is the center is as follows: Riverside, 10,000 acres; Gage canal, 15,000; South Riverside, 6,000; North Riverside canal, 7,500; Vivienda pipe line, 5,000; Rincon ditch, 4,000; a total of 47,500 acres.

F. C. Finkle, San Bernardino, engineer Jarupa system (January, 1892):

Water supply: Santa Ana River and cienegas (wet subsoil); 30 cubic feet per second at present.
Works: Main canals, 18 miles; small reservoirs for distributary purposes; 74 head gates; 200 miles of laterals; subcanal into cienegas 1 mile, 5 to 20 feet deep.
Cost of: drainage, cut or sub-canal, $30,000; earth canal, $11,000; cemented ditch, $3,600; flume and trestlework, $10,000—in all, $54,600.

Area served: Under ditch, 10,000 acres; under cultivation, 3,000. Cost of supply, $50 per acre; annual rental, $2 per acre.

SAN DIEGO COUNTY.

D. Goechenauer, San Diego (post-office), 1891:

Fruit-tree planting during 1891 has been on an extensive scale. Of citrus and deciduous trees about 900,000 have been planted during the year. The fruit bearers for 1892 will not be less than 500,000 trees, an increase of 200,000 for the past year. During 1891, out of San Diego city there were shipped 2,820,000 pounds of raisins, or about 142 cars, as against 88 cars last year. There were 66 carloads in 1890 from the San Diego Bay section. Of this total, Spring Valley and El Cajon furnished 12 carloads, and Sweetwater, Paradise, and Tia Juana valleys furnished 42 carloads. The other 10 cars were raised in Jamul, Lyons Valley, Otay, National Rancho, and other tributary valleys.

SAN JOAQUIN COUNTY.

J. D. Huffman, Lodi (October 13, 1891):

Water supply: The Mokelumne River.

Works: Main canal, the Woodbridge, at present 12 miles in length; large dam across the river, made of piles and timber, of which 500,000 feet have been used. Piles have been driven from 13 to 28 feet; crest of dam 6 feet below low-water mark. There are 22 gates, by closing which the canal can be flooded. The dam, which is on the weir or overflow principle, will permit the high water to flow over its crest; the channel is 200 feet in width.

Area to be served is now 50,000 acres, but it is expected that canal and reservoir will serve 170,000 acres.

SONOMA COUNTY.

H. J. Schroobeda, Petaluma (October, 1891):

All irrigation is chiefly from wells, and confined to fruits and gardens. There are 5 miles of ditches.

Cost per acre estimated at $20; total cost of such works $24,000 in my neighborhood.

Under irrigation here, 45 acres. Water plane, 10 feet below surface; water costs about $20 per month. Product is rated at $250 per acre.

TULARE COUNTY.

N. W. Motheial, Hanford (October, 1891):

Water supply: Kings River.

Ditches serving neighborhood are the People's, Last Chance, Lake Side, Lower Kings River, and Mussel Slough. People's Ditch is 25 miles in length, 40 feet at bottom, 5 deep, and falls 1 foot to the mile. These ditches cover 125,000 acres.

Ground is level no timber; ditching cheap; preparing land easy. Cost, $1 per acre; with ditch, $1.50; annual maintenance, 50 cents per acre; cost per mile, in all about $3,500. One dam in river, cost $7,000; one head gate.

Under cultivation (People's Ditch), 25,000 acres. Crops: Corn, wheat, alfalfa, deciduous fruits of all kinds; some citrus orchards in sheltered places.

P. Y. Baker, director in Alta irrigation district (Tulare and Fresno counties), Tulare (September 22, 1891):

Water supply: Kings River, mountain stream fed from higher Sierras; carries 30,000 cubic feet per second during season from May to August.

Works: Canal 100 feet on bottom, 18-inch fall, slope 3 to 1, 5 feet of water; numerous laterals; 1 main head gate; 628 farm gates.

Cost of main canal, $1,200 per mile. System has cost district $3.75 per acre in 6 per cent twenty-year bonds.

Area under ditch, 130,000 acres; under cultivation, 124,000. Organized under district law.

Cost of water: 42 cents per acre per annum.

Cost of cultivation: Meadow and fruit land, $10 per acre.

Product per acre: $25 to $40 in value.

Crops raised: Wheat, oats, barley, corn, potatoes, vegetables, raisins, prunes, peaches, apples, nectarines, oranges, lemons, olives, apricots, pears, wine grapes, alfalfa, blue grass, nuts of all kinds.

George H. Weaver, secretary "Alta" district, Dunbar (September, 1892):

Water supply: Kings River. District organized under Wright laws.

Works: Head gate; dam; 25 miles of main ditch; many more of laterals; one reservoir of 100 acres; 1 head gate.
Cost per mile, $600.
Area under cultivation, probably 40,000 acres.
Cost of supply to user by tax levy, 38¼ cents. Under district system tax levy is 80 cents on $100 of valuation; interest, 20 cents; maintenance, 13 cents; administration, 5¼ cents per acre. Cost to user before district formed was: royalty, $5 per acre; annual rental, $1 per acre.

E. A. May, secretary Poplar Irrigation Company, Tulare (October, 1892):

Cost of preparing, $9 per acre, under favorable circumstances; with ditches for irrigation, $15 per acre.
Cost of water to user, from 50 cents to $1 per acre per annum.
Area cultivated by Poplar Ditch, 1,400 acres.
Products: Chiefly alfalfa, hay, vegetables, fruits, raisin grapes. Yield: Fruit, from $100 to 250 per acre; vegetables, from $200 to $300.

VENTURA COUNTY.

W. W. Blanchard, Santa Paula:

No regular irrigation.*
Small ditches and wells are used for irrigating gardens, orchards, and alfalfa; but chiefly for stock and domestic purposes. Citrus fruits are irrigated.

YUBA COUNTY.

J. McFarlane, secretary Brown Valley irrigation district, Brown Valley (post-office), October, 1891:

Water supply: North or main fork of Yuba River; abundant at all seasons.
About 43,000 "under ditch;" cultivated; no reply.
Irrigation works are under construction: Main ditch of about 20 miles; 7 miles of flume; ditch 5 by 7 and 2¼ feet deep; main dam across river: base, 100 feet; top, 150; height, 26 feet; cross-section, 26 by 40; double head gate; branch ditch, 5 by 7, 2½ deep; iron piping, 1,600 feet, to convey water across a creek.
Cost of dam by contract, $8,500; flumes and ditches, $72,000.

E. A. Forbes, Yuba City (post-office), Sutter County (September 22, 1891), writes of the Brown Valley district, Yuba County:

Water supply: North Yuba River, 30,000 miner's inches.
Works: 8 miles of flume, 20 miles of main canal, 22 miles of distributing ditches; 3,300 feet of 30-inch iron pipe; one dam 26 feet high (in river), 140 feet across, 40 feet base, peeled spruce logs, inside perpendicular, 2 screw head gates, one suspension bridge.
Cost: Ditch, $1,500 per mile, average; fluming, $1 per foot; piping, $3; bridge, $6.50; dam, $7,500.
Area under ditch, 44,000 acres; under cultivation now, 3,500 acres; 35,000 can be irrigated.
Cost to user: About $3 per acre when laterals are all completed; maintenance annually, 20 to 30 cents per acre.
Cost of preparing land, $5 per acre; add irrigation cost, $8 per acre.
Annual product per acre: My estimate is, strawberries, $900 per acre; blackberries, $500; oranges, $700 to $1,000; peaches, $250 to $350; wheat, $10 to $25 or $30. The place is no good except for stock-raising, and small crops of hay without water; with water it is a bonanza.

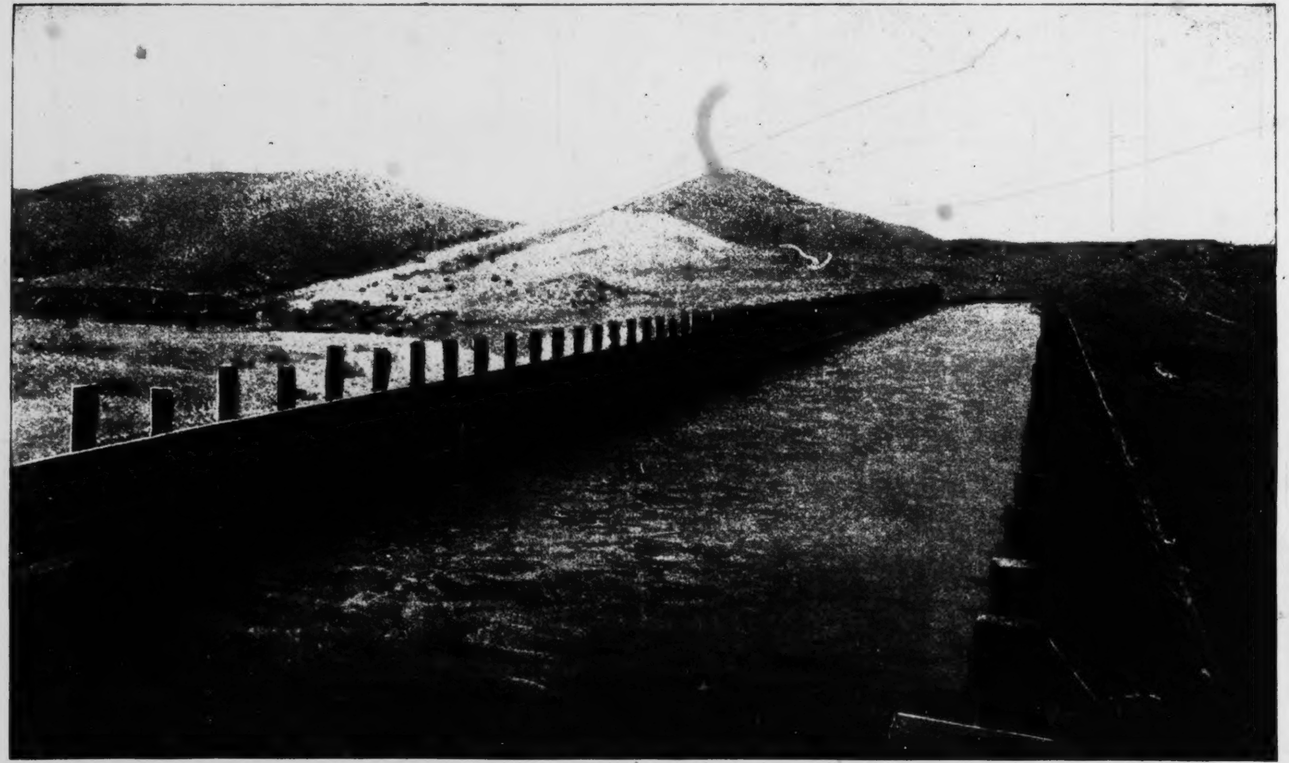
COLORADO.

Irrigation in the Centennial State continues to make serious and steady progress. It is developing in many different directions, especially in the matter of storage, but the chief growth has been, in the judgment of this office, in the way of reclaiming many comparatively small areas, in the extension and betterment of neighborhood systems of distribution, in the increase of local storage efforts, in the development of supplies from springs, undersheet, or drainage sources, of bed-rock dams, wells, artesian or otherwise, in the better knowledge or practice of economy in the use of water, in the increase of fruit culture, and generally of smaller farms and intensive cultivation. Coupled with the active and intelligent interest displayed in irrigation legislation and administration the progress of Colorado is quite satisfactory.

The fifth biennial report of the State engineer, J. P. Maxwell, for 1889-'90, is the latest authoritative statement of the administrative conditions of irrigation. The following table has been prepared therefrom:

[Condensed from State Engineer's Report, 1888-'90.]

Division.	District.	Reservoirs.	Capacity claimed.	Ditches.	Mileage.
			Cubic feet.		
No. 1	1	4	12,687,128	11	124
	2	12	39,584,332	31	236.50
	3	11	192,336,426	62	351.14
	4	8	343,132,944	14	176
	5	6	304,491,232	65	244
	6	19	369,416,960	67	258
	7	73	262,955,271	59	255.63
	8	15	1,648,465,308	132	267
	9	28	1,929,236,027	22	65.25
	23	5	3,643,517,407	228	912
	46	1	1,119,208	88	332
	47	....	....	158	482
	64	....	....	10	98
	65	....	....	3	12
No. 2	10	30	120,673,455	127	508
	11	7	260,792,156	122	488
	12	10	226,781,600	48	85
	13	....	....	27	108
	14	39	1,470,211,538	16	64
	15	2	....	46	88.50
	16	2	1,546,632,250	191	764
	17	3	....	9	305
	18	....	....	4	16
	19	1	13,454,000	29	116
	49	....	....	4	16
	66	....	....	4	8
	67	....	....	27	108
No. 3	20	....	1,000,000	54	216
	21	....	....	69	164.50
	22	2	160,000,000	62	160
	25	1	64,000,000	200	312
	26	....	....	36	144
	27	3	109,000	8	32
	35	2	20,700	11	46
	20	....	....	3	12
No. 4	30	....	....	7	28
	32	....	....	1	4
	83	....	....	7	28



No. 1 Flume, Colorado Canal, Arkansas Valley, Colorado.

Division.	District.	Reservoirs.	Capacity claimed.	Ditches.	Mileage.
			Cubic feet.		
No. 5	28			36	
	37	1	3,750,000	140	560
	38	7	2,273,000	43	100.90
	39	17	27,795,000	13	24.50
	40	22	501,388,682	74	88.38
	41	5	24,175,800	70	280
	42	10	75,551,209	85	226.32
	45	3	11,200,000	67	87
	50			3	12
	51			6	24
	52			10	40
	53	1	318,655	19	76
	59			11	44
	60	1	266,666	3	12
	61	2	304,300,000	1	4
	63			4	16
	68			1	4
No. 6	43	4	6,802,783	87	133.55
	44			19	76
	54			3	12
	57	1		26	104
	58	2	1,465,120	84	336
	11.60	360	13,569,903,857	3,267	9,793.17

The state engineer's report shows for 1890 a total of—

Individual ditches for which decrees of water have been issued and filed in the engineer's office, 1890	1,673
Filed from 1887 to 1890	2,040
Total	4,311
Total mileage of ditches as far as constructed, 1890	11,052.90
Total area under ditch, 1890	4,082.738

But the total acreage irrigated reported by the water commissioners for thirty-four districts was only as follows for 1890:

	Acres.
In alfalfa	161,854
In cultivated grasses	42,592
In natural grasses	389,430
In other crops from ditches	437,147
In seepage water from ditches	18,546
Total reported	1,063,304

No report of the orchard, small-fruit, garden, and vegetable areas within the State is given. It is certainly not less than 60,000 acres. There are many small irrigations which escape attention and are not reported because they are in sections where no appointment of water commissioners has been made. The small-area irrigation is on the increase. It is not too much, therefore, to estimate the area of irrigation in 1890 at 1,700,000 acres, and for the year 1891 an increase of 100,000 acres, or 1,800,000 irrigated and cultivated acres.

Engineer Maxwell estimates that for 1890 there were irrigated from stored water within the area of water division No. 1—that is, the valley of the South Platte—about 100,000 acres. He says (p. 17 State Engineer's Report):

> The stored waters being used in connection with that running in ditches renders it impracticable to determine accurately the acreage irrigated therefrom, but the figures are given as close approximations
>
> Colorado is, evidently, now entering upon an area of reservoir construction, the necessity for which has become apparent wherever there is a deficient water supply during the irrigating season, and as there is an element of danger connected with such improvements, all possible safeguards should be provided against such disasters as have occurred in other sections of the country within the past few years.

An important discussion is given as to the duty of water. The State engineer says (pp. 46–49):

> The waters of the eastern slope being very closely appropriated and the means of diversion provided, it is not of so much importance to determine the present duty of water for future canal development as to realize its maximum duty for the better cultivation of lands already under ditch. Whatever service water may perform at this time, we know that service can be increased by eliminating many of the sources of waste apparent on every side. The varied conditions of soil and surface preclude the possibility of a uniform standard, but there are local causes for a diversified duty, even where the lands are not appreciably different.
>
> Water rights vested on a basis of the low duty assigned to water ten years ago have, in instances, deteriorated lands and reduced their productiveness by a surfeit in application, while on adjoining lands, through an enforced economy, a higher duty, better condition of the soil, and greater productiveness have resulted.
>
> Unskilled labor has a penalty of 25 to 50 per cent attached to it in the application of water, and unfortunately this class is too prevalent in the irrigating fields, in many cases no other being obtainable.
>
> An abundant water supply tends to carelessness in its application and consequent waste. Where liberal and old water rights are provided it is frequently the practice to turn the water upon the land and permit it to run without change or attention throughout the night, and sometimes during the day, a large volume of the water soaking into the soil without benefit to the crop.
>
> * * * * * * *
>
> The duplication of ditches is another fruitful source of waste, reducing the duty of the volume of water, as indicated by the gauging stations in the cañons.
>
> The paralleling of ditches at inconsiderable distances apart, the upper one of which could be made to answer the purposes of all with marked economy in water, as well as a large saving in capital, is also indicated as a great cause of waste.
>
> Too little attention has also been given to the proper preparation of the surface to facilitate the rapid spreading of the water. This is principally the result of too large individual ownership of land, rendering it impracticable to give close supervision and secure careful preparation of the land. The best results will be obtained from small proprietory rights in land and a consequent higher state of cultivation. The ownerships of the cultivated lands of the State should be multiplied by ten and the population increased to that extent.
>
> We are enabled to give some general results as to the service water has performed in some of the older districts of the State, for the two years last past, based upon the gaugings of the several streams at the cañons and the areas under cultivation, as reported by the water commissioners.

Tabulated statement of water duty on streams indicated for 1889 *and* 1890.

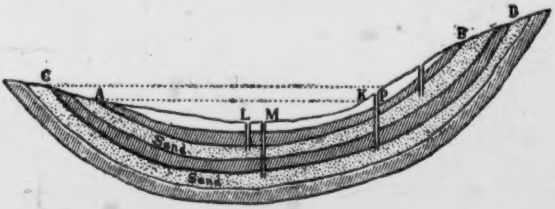
[Report of State Engineer of Colorado.]

Streams gauged.		Mean discharge from May 20 to Sept. 20, per second.	Area cultivated.	Equivalent in depth over area.	Rainfall during period.	Total depth over area.	Duty per cubic foot.
		Cubic feet.	*Acres.*	*Feet.*			*Acres.*
Cache La Poudre	1889.	735.97	139,222	1.178	.682	1.860	189.168
	1890	770.51	139,222	1.254	.338	1.592	180.687
Big Thompson	1889	214.53	91,037	.579	No data..	....	424.35
	1890.	425.42	89,790	1.192	No data..	....	211.06
St. Vrain	1889.	215.46	94,013	.563	.532	1.095	436.33
	1890	284.238	94,365	.739	....	....	332.69
South Boulder and Boulder Creek	1889	461.97	77,682	1.406	....	....	168.15
	1890	419.33	76,682	1.34	....	....	182.86
Bear Creek	1889.	60.40	10,173	1.46	....	....	168.42
	1890.	33.98	8,112	1.03	....	....	239.02

The review of the State, after these general statements, has been confined to an examination of certain sections showing special growth in reclamation by irrigation, with features that require particular attention, and which were personally investigated during the journey of the special agent in charge in the summer of 1891. The story of the Union Colony's "Community Ditch No. 2" is one of great interest to all who are engaged in the work of cultivation by means of irrigation and to those who are investing in canal enterprises. It illustrates what may be done by association. One of its most marked features is the almost entire absence of litigation. This fact, combined with the economy of service, makes "Community Ditch No. 2" one of the most noticeable irrigation enterprises in the United States. All the statements have been personally verified by an examination of accounts and by the testimony of those operating under the ditch. This work was carefully performed by Mr. M. A. Downing, under direction of the special agent. The San Luis Valley report illustrates the magnitude and character of large canal enterprises, as well as the remarkable development there of artesian wells and other phreatic supply. The engineering character of the Upper Arkansas Valley works are notable, and the methods of water administration are worthy of note. In addition there are summaries of information replies received by this office, as well as obtained by personal investigation.

Prof. Louis G. Carpenter, of the State Agricultural College, has during the year published an interesting report on the artesian wells of Colorado in which he gives a clear and concise account of the interesting development of such supplies. Prof. Carpenter's ability and experience adds value to his figures and deductions. He says:

> The conditions for the existence of an artesian well basin are that there should be some source of water supply higher than the location of the well, and that there should be a porous stratum which is confined by impervious strata both above and below. This strata must be continuous. In general the water should have no means of escape lower than the point where the well is, but when the distance to an outlet is considerable the friction in the intervening distance may be more than sufficient to make up for the difference in level. The pervious stratum may consist of any material which will allow water to pass through it, but most commonly it consists of sand or sandstone. The more open and porous this stratum is, the more abundant will be the flow with any given pressure. No rocks are perfectly impervious, but thickness will compensate to a great extent for a slight porosity. The confining stratum generally consists of clay or shale.



> The region where artesian wells are found is generally spoken of as an artesian basin, largely because the typical form of such a region is a genuine basin, with the rim higher than the center. A section of the Denver basin is of this form. The figure may represent an exaggerated section of such a basin, with a porous strata outcropping at B, D, C, and A. Anywhere lower than the line A K flowing wells might be expected if the strata are continuous, but as we reach K, or some point nearer B, it will be found that water comes only to the surface, and still higher it may fail to reach the surface. It is also evident that while at P flowing water will not be obtained from the upper stratum, by going deeper it may be secured, because the outcrop of the stratum which furnishes it is higher.
>
> "The figure also shows why the pressure is generally greater as the depth is greater. This fact has given rise to a popular belief that if one only goes deep enough flowing water will surely be obtained. Unless the proper conditions are present this is not true, and it is useless to expend money in that hope.
>
> "The supply of water which comes from a well, or series of wells, is never unlimited, though it may be very large, as in the wells of Dakota, or in some of those in

the San Luis Valley. Its limit is set by the amount which is supplied to or absorbed by the water-bearing stratum, from water which falls on or flows over the edges of the strata. Where the strata reach the surface at a small angle the area exposed to absorption or to rainfall is much greater, and the case is more favorable than where the angle is great. The capacity of the wells is limited by the amount these edges can absorb, or to the supply which may fall upon them. The edges may be covered by surface soil, or may be less pervious, in which case the conditions are less favorable for a large supply. If the number of wells is increased largely in any basin, there generally arise indications of a limitation of the supply in the effect of one well upon another, or on the general flow. When such a point is reached it is time that some consideration be given to the conditions, for the value of such a supply can not be overestimated. Its value becomes greater with the increase of population. When many wells are put down in a small area, the decrease, which is generally noticeable, may not indicate that the general supply is overdrawn, but that the local supply is—that is, the water flows from the wells faster than the supplying strata furnish it."

On the value of water in connection with an artesian supply Mr. Carpenter gives the price of water right per 80 acres in the older sections of Colorado as "rarely less than $1,200 * * * Such a right generally means 1.44 cubic feet per second." The cost of a water right "would be about $780 per second-foot, but based on the amount actually received it would probably be four times that." He gives an instance of the purchase of drainage water on the Cache la Poudre Canal No. 2 at the rate of $3,000 per second foot. Prof. Carpenter says:

If water has reached such value in a community not more than twenty years old, and that, too, where tropical fruits or the large returns of a more torrid climate can not be expected, it may well suggest that before many years it may pay to expend sums for the development of supplies which would not now be thought of, and it impresses the economic importance of conserving such supplies as we have and of utilizing them to the fullest extent.

One advantage in the artesian wells is in their continuous flow, as in the case of the drainage water above mentioned. In most streams of the State the water is high for a short time only during the season, and during July and August it becomes scanty, so that late crops often suffer in consequence. The surplus water of June runs to waste. Where the flow is uniform throughout the season, a duty of some three or four times that used as the basis of water rights in Colorado may be expected.

The flow from many of the wells is small, so small that the owners think it is of no use in irrigation, and therefore allow the water to run to waste.

In other countries a stream no larger than a pencil is highly prized. In Sicily, for example, water is measured by an orifice or pipe known by a term equivalent to a "goose quill." The same is the case in the Island of Madeira. Throughout Asiatic countries, and especially in China and Japan, the utmost care is taken in economizing the smallest stream. Mr. Carpenter continues:

The stream alone could effect no irrigation of consequence, but by running into a small reservoir it can be stored, and then a large head used for a short time. The greater effectiveness of a large head is well known in Colorado. In a similar way the water from many of the wells, which now runs uselessly away, could be made to perform a service which would be considerable in the aggregate. Some are already being utilized in this way to a greater or less extent, but generally without storing.

The cost of sinking generally increases more rapidly than the depth, so that except in exceptional cases, such as extremely easy boring, as in the San Luis Valley, or great supplies of water, as in Dakota, it will not pay to attempt deep wells for irrigation purposes. The temperature increases with the depth, which is an advantage if the water is to be immediately applied; but the water is also more mineralized, which is a disadvantage or not, according to the character of the solids present.

On the several basins in Colorado, the professor gives his conclusions as follows:

The wells of the Denver basin have been put down almost exclusively for domestic water. There has been comparatively little thought given to their use for irrigation; nevertheless many of the wells are irrigating areas of from 1 to 10 acres. Nearly all

> those in the country are used to irrigate gardens. Some are used for the raising of fish. The cost of the well, taken with the small amount of water obtained as a rule, prevents many being sunk for irrigation.
>
> * * * * * * *
>
> The uniform appearance of the valley (Rio Grande), as well as the conditions which have made it an artesian basin, is due to the fact that in former geological times it was an immense lake, formed by the damming of the Rio Grande by the large mass of basalt in the lower end of the valley, and which is probably also the cause of the abrupt bending of the Conejos and other rivers to the north. In consequence of the late formation, the characteristics are fairly uniform over the whole area, though there is much variability, as is to be expected, in the thickness and number of the strata. Near the ancient bed of the Rio Grande there is especially great variation; elsewhere there is great uniformity over considerable distances. The water is found everywhere, so far as learned, above the rock, which, in the western part of the basin, is comparatively near the surface, but at Alamosa is not found in the well which is 1,000 feet deep. The wells are sunk so easily and rapidly that few records are kept of the strata passed through, but the following, taken by J. M. Chritton, in T. 39 N., R. 9 E., is typical of the whole district.

Strata.	Thickness.	Depth.	Flow.
	Feet.	*Feet.*	
Dark, sandy loam	7	7	
Coarse sand and gravel	13	20	
Fine light-yellow sand	22	42	
Yellow impervious clay	18	60	
Blue clay or soft slate	98	158	
Black sand	1	159	Small flow.
Blue clay	4	163	
Fine black sand	3	166	Fine flow.
Blue clay	45	211	
Fine black sand	12	223	Flow.
Blue clay	53	276	
Black sand; flow so strong that with our pump we could not go deeper.			

The cost of the small wells flowing from 5 to 25 gallons per minute through a 2-inch pipe is as a rule from $25 to $75. Irrigation was not specially considered when wells were first sunk. Mr. Carpenter continues:

> Where the flows are large they are used to some extent, and sometimes small reservoirs have been built for storage. The 3-inch well of Espinosa, already mentioned, is said to irrigate some 100 acres of hay land. J. M. Chritton writes that he was irrigating 16 acres in 1889 from one well. L. W. Smith, a few miles west of Alamosa, irrigated 40 acres of crops, consisting of oats, wheat, barley, rye and potatoes, from two 3-inch wells, in 1889, and stated that he intended to farm 100 acres during the present season by using a reservoir of 1¼ acres. Several wells in the vicinity of Espinosa furnish water for irrigation.
>
> The supply of water from the river is not yet fully used, so there is not so much inducement to consider means of using water in the quantities furnished by most of the wells, but with the closer settlement of the valley there is no doubt they will be of considerable importance in the aggregate.
>
> The water furnished by the Bucher deep well at Alamosa exceeds one cubic foot per second, and the cost was $2,700, so that, if water should reach the value it has in the older farming communities, such a well might be considered a good investment.

The necessity of knowing the limit of supply is strongly presented. The best practical test is the observation of the pressure, and that "depends principally on the height of the water level above the point where the test is made." Mr. Carpenter states of the San Luis Valley, that—

> The source of the supply for the wells is to be found at no great distance in the streams from the mountains which pour their waters into the sands of the western part of the valley, and to a lesser extent from the streams of the eastern side. These have gradually raised a delta of sand where they enter the plain higher than the basin proper and consisting of a coarser débris which has been brought down. Farther out in the valley the beds of clay begin. All of the smaller streams are entirely lost in these beds of débris, as the map shows. Of those which do not disap-

pear it would be interesting to know whether there is any marked diminution of their volume in passing over this absorbing area. The watershed of the smaller streams from the west, which entirely disappear, is some 460 square miles of the Saguache and San Luis creeks, about 1,300. The amount brought into the valley by means of these streams is unknown, but the ratio it bears to the area of the watershed will be approximately the same as in the case of the Rio Grande. The discharge of the Rio Grande, as measured at Del Norte, corresponds to a depth of 12 inches very nearly over the whole watershed. Assuming the same depth as the amount flowing off from the smaller streams, their total flow would average about 330 cubic feet per second. An unknown amount comes from the San Luis and Saguache creeks and from the mountains of the east. If we assume that this may be as much more, as seems a reasonable estimate, the total amount available would be some 600 cubic feet per second.

Taking all these sources into consideration it seems safe to conclude that while the supply will most likely exceed 600 feet per second it is not apt to reach 1,500. The average flow of the present wells in the valley may be taken as 25 gallons per minute, whence their combined flow is in the neighborhood of 110 cubic feet per second. It is probable therefore that the number of wells may be increased until the flow is six times as great, but not likely that it may become fifteen times as great. Assuming the smaller amount as the amount of water eventually available, if it were all used in irrigation it might irrigate at seventy acres to the second foot some 42,000 acres, and if used with storage three or four times as much.

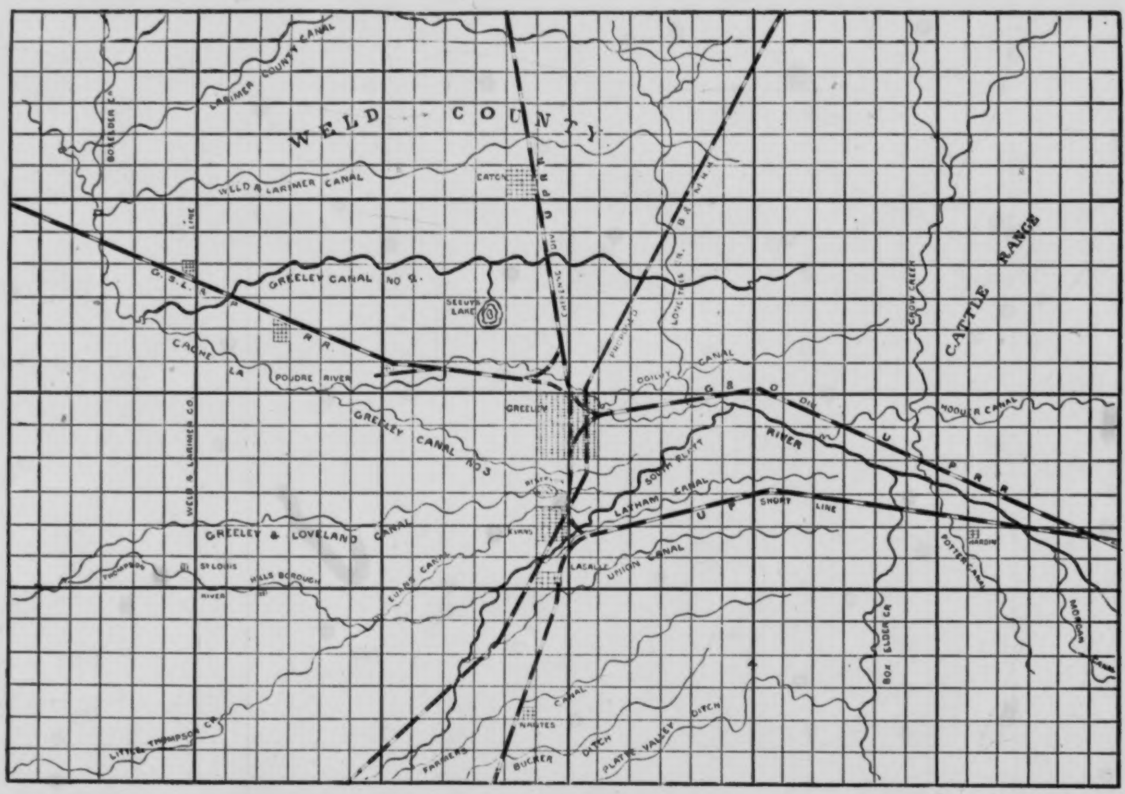
COÖPERATIVE IRRIGATION IN COLORADO.

The Union Colony of Colorado was the earliest organized effort to farm by irrigation. Before its organization there had been no irrigation in the United States worthy of the name, unless at a few points in California and among the Mormon farmers of Utah. The name "Union Colony," the suggestion of Mr. John Leavy, expresses fully the purpose of the founders. In 1870, under the leadership of N. C. Meeker, the colonists founded Greeley and coöperated to accomplish the difficult task of irrigating from one source 25,000 acres of land. Each farmer was to own his own land in fee simple, but the irrigation canal was to be the property of the community. The land selected for this experiment lies on the banks of the Cache la Poudre, which rises in the snowy range of the Rockies and after a precipitous course of 30 or 40 miles debouches on the plains, where the fall is from 10 to 15 feet to the mile. At the outset four canals, forming a system, were projected, but for various reasons all but No. 2 and No. 3, as they are now called, were abandoned. No. 2 canal is a community ditch, owned and operated by the farmers and is probably the most economically managed canal in the United States. The circular of the Union Colony promised the farmers who took lands that:

> Land is to be furnished with water for irrigation. The colony digs the ditches and each member of the colony is liable to an assessment for keeping the same in repair. It is estimated that the ditches for irrigating the lands of the colony as stated [it was then proposed to irrigate about 60,000 acres] will cost about $20,000, for which there is money in the treasury.

This promise was not redeemed by the colony, and the expense of the final construction of the ditches was far in excess of the amount originally appropriated out of the funds contributed by the colonists.

The history of No. 2 Ditch is the only part of the story of the Greeley colony that is important in this report. It takes its water out of the Cache la Poudre River, 17 miles west of Greeley. The first work was done on it in the fall of 1870 and the spring of 1871, but it was then only a small affair. As originally constructed it was 26 miles long, with a fall of 3 to 4 feet per mile, 10 feet wide on bottom for the first 5 miles, 9 feet wide for the second 5 miles, and diminished in the same proportion throughout its length. It carries about 2½ feet of


WELD COUNTY
LARIMER COUNTY CANAL
BOXELDER C.
WELD & LARIMER CANAL
CATON
U P R R
CHEYENNE DIV
LINE
G. S. L. & P. R. R.
GREELEY CANAL NO 2.
SEELEYS LAKE
CACHE LA POUDRE RIVER
B & M R R
PROPOSED
LONE TREE CR.
OGILVY CANAL
GREELEY
G & O DIV
CROW CREEK
CATTLE RANGE
HOOVER CANAL
WELD & LARIMER CO
GREELEY CANAL NO 3
GREELEY & LOVELAND CANAL
RIVER
SOUTH PLATTE
LATHAM CANAL
U P SHORT LINE
EVANS
THOMPSON
ST LOUIS
HALS BOROUGH
RIVER
EVANS CANAL
LASALLE
UNION CANAL
HARDIN
POTTER CANAL
BOX ELDER CR
MORGAN CANAL
LITTLE THOMPSON CR
CANAL
NASTES
FARMERS
BUCKER
DITCH
PLATTE VALLEY DITCH

COMMUNITY DITCH No. 2, WITH OTHER CANALS SUPPLYING IRRIGATED LANDS AT GREELEY, COLORADO.

water. The cost amounted to $27,000, and only 2,000 acres were partially irrigated. The situation of the colony at the close of 1871 was very critical. Instead of four ditches and an irrigated area of 60,000 acres the farmers were confined to about 2,000 acres of partially watered land. At this time, besides the No. 2 Canal, No. 3, a small town ditch, furnished a little water. Water rights in No. 2 had been sold for 320 80-acre tracts. To meet the difficulty two assessments, amounting to 35 cents an acre in all, were levied on all lands to be watered by No. 2, which realized about $7,960. This sum was paid by the farmers themselves, independent of the liability of the colony organization. The colony, out of the funds received from the sale of its colony membership certificates, made up the balance of the cost of the first enlargement. This work was completed before the close of 1872. There are no records from which to ascertain the cost of this enlargement, but, assuming that it cost as much as either of the other two subsequent enlargements, it must have been in the neighborhood of $20,000. In 1877 the canal was enlarged for the third and last time, and from that time forward has furnished sufficient water for all the water rights, or 320 cubic feet per second.

In 1878 the organization known as the Union Colony of Colorado turned over all the rights in the canal to the farmers under it, who organized and incorporated as the "Cache la Poudre Irrigation Company," and since that date have managed the canal by a board of directors. The question of the cost of the No. 2 Ditch is much mooted, and it is only by analysis that the same can be ascertained. Union Colony expended the first cost, $27,000, out of the colony funds. To provide for the first enlargement the farmers assessed themselves 35 cents per acre, making in all $7,960. This being insufficient, Union Colony, as such, contributed $12,040 additional, making in all for that enlargement $20,000. The colony thus paid for the ditch, before its interest ceased, $39,040. The minutes of assessments since 1885, the earliest record in the office of the secretary of the Cache la Poudre Irrigation Company, are as follows:

Year.	Assessments per water right (80 acres) of—	Total amount.
1885	$20	$6,400
1886	14	4,480
1887	12	3,840
1888	9	2,880
1889	9	2,880
1890	16	5,120
1891	16	5,120
	.. ..	30,720

During the seven years mentioned this would be an average annual assessment of $13.72 per water right for 80 acres, or $17\frac{15}{1000}$ cents per acre. The officers of the present company, the secretary of the colony, Henry T. West, and all the original colonists agree that the expenses for the thirteen years previous to 1885 would average no higher. Therefore up to 1885 the cost of the ditch to the farmers would be $57,075.20; cost to colony organization, $39,040; cost of maintenance since 1885 of $30,720, which would make a total cost of $126,835.20. The item of $39,040, as explained above, is $27,000, first cost of ditch, and $12,040, estimated amount contributed by the colony organization in addition to the farmers' assessment, to pay for the first enlargement. The Greeley No. 2 Ditch has therefore cost the owner of each 80-acre water right during twenty years a total of $396.36, or $4.95 per acre.

The legal name of the company now operating this canal is the Cache le Poudre Irrigation Company. The stock is divided into 2,600 shares. It is supposed that a share will irrigate 10 acres. The original 80-acre water right given the colonist represents eight shares of stock. The new company was formed in 1878, but the use of the water had all been disposed of by the Union Colony, and all that passed to the company was the administration. In the river bottom there are about 1,800 acres under this ditch that need constant drainage instead of irrigation in consequence of the soil filling up by seepage. Five years ago the North Side lateral was made, and the shares above spoken of transferred to that ditch, thus saving the water by putting it on new land. The present value of an 80-acre water right in this canal is estimated by the owners at more than $2,000, according to the latest sale made by Henry Williams, one of the original colonists. The present value of the ditch is therefore $640,000. A 40-acre tract of land with water for 80 acres was sold by the colony in 1870 for $150.

The canal is 36 miles long, 32 feet wide on bottom, slope of banks 1 to 1, and fall 3 feet to the mile. This fall is entirely too great, and the bulk of the expense of maintenance since 1878 has been caused by the expensive "checks" or board dams made necesary owing to the constant erosion of the canal bed. Of the 25,600 acres under No. 2 Ditch 6 per cent of the same, or 4,400 acres, is filled up by seepage, and the farmers, when possible, apply this water to other lands. This seepage water will come to the surface in low spots clear from the ditch to the river wherever hardpan crops out. Besides this there are several small lakes formed by turning in surplus water from the canals and seepage. The annual crop division of this 25,600 acres is approximately as follows:

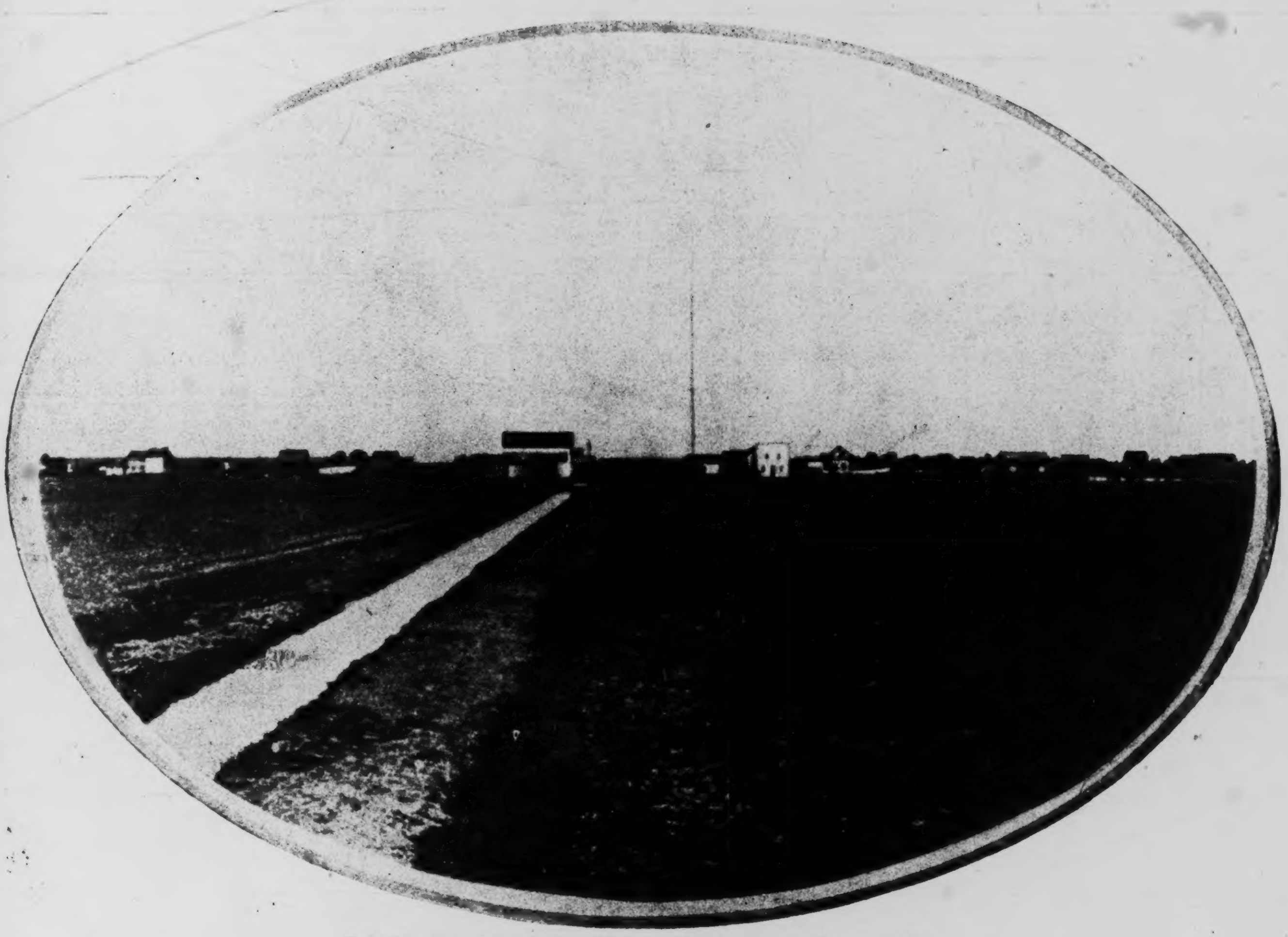
Potatoes, 5,000 acres, yielding an average of 100 sacks to the acre, 110 pounds to the sack, at an average price last year of $1.35 per hundred-weight.

Wheat, 6,000 acres, yielding 30 bushels per acre, at $1.32 per hundred-weight.

Alfalfa, 6,000 acres, yielding 3 tons per acre, at from $5 to $6 per ton.

Barley, oats, and corn, 4,000 acres, yielding 35 bushels per acre, at corn, $1.15 to $1.60; oats, $1.25 to $2; barley, $1.40 per hundred-weight, and the balance of the land is divided into vegetable and garden land. This shows an average value of product of $50.10 per acre on the staples named.

It will be interesting to contrast No. 2 Canal, as built by the Union Colony, with the Larimer and Weld Canal, built by a corporation, which is practically along the line of No. 1 Canal, projected by the colonists, but never taken out. Col. E. S. Nettleton was the engineer of both. The ditch built by the Union Colony, and since maintained by the farmers, has cost for construction and maintenance, during twenty years, $126,835.20, or $3,459 per mile. The Larimer and Weld cost $3,000 per mile for original construction, or $156,000 as first cost of its 52 miles of length. A water right in the latter ditch sold for $15 per acre, or $1,400 for an 80-acre tract. The annual rental is $10 for 80 acres, or 12½ cents per acre. If the Larimer and Weld Canal had been in use for twenty years the expenses for water to an irrigator would have been $1,600; that is, $20 per acre, or $1 per acre per year. Under No. 2 it has been shown that the expense of building and maintaining a ditch for twenty years is $396.36 per annum for 80 acres,



First Irrigation Colony in Arid America. View of Greeley, Colorado, 1870.

or $4.85 per acre, or 24¼ cents yearly per acre. This sum includes cost of building, enlarging, improving, and maintaining. The Larimer and Weld Canal is 28 feet on bottom, 6 feet deep, and 1¼ to 1 slope of banks, making the canal 46 feet wide at the water line. When first constructed the work was better than that of No. 2, but the enlargement and repairs of the latter have made it at least the equal of the Larimer and Weld.

Another feature to be considered is that there has been no litigation of any consequence under the community ditch, while under the Weld and Larimer it has been frequent. Law proceedings on No. 2 have only been of a character designed to settle questions of appropriation. In June, 1891, there was an important decision affecting the corporation canal. The water contracts with the users of its water provide that the corporation shall not attempt to sell water for use in excess of its appropriation, and that the canal shall be turned over to the irrigators when all the rights are sold. The canal is only entitled to the surplus flow of the Cache la Poudre after No. 2 and No. 3 have been satisfied. In dry seasons it is alleged, therefore, that there is not sufficient water to supply the Larimer and Weld irrigators, and therefore the people sought to enjoin the company from selling any further rights based on the supply in sight, setting forth that there was not water enough for the present users. The court held that the corporation could sell water rights up to the full carrying capacity of the canal, and that the supply could not be taken into consideration as a basis of estimating the number of water rights that might be sold under the restrictive clause of the contract. Among themselves owners in No. 2 have had no litigation.

On No. 2 ditch, where each water right is entitled to one three hundred-twentieth part of the flow of the ditch, such litigation is impossible; but the irrigators having the right to determine where and when their water shall be delivered, a custom has grown up by which two or three water-right owners will consolidate their supply during dry seasons and use the combined flow in rotation, thus affording ample water to the users for rapid irrigation during the dryest seasons.

No. 3 canal, projected by Union Colony, was begun in 1870, and completed by three enlargements in 1871, 1872, 1873. The original cost was $6,333, but the enlargements, dams, improvements, and maintenance during the past twenty years, have increased the cost to about $25. Its water is used for the irrigation of the city of Greeley, and surrounding gardens. No large tracts are cultivated under it. An original colony certificate, costing $150, entitled the holder to water from this ditch for his house lot and a piece of ground not to exceed 10 acres. It is still owned by the irrigators and is run similarly to No. 2. The great fault in the early construction of these canals was the persistent attempt to keep the canals "in the ground." They zigzagged along the notched bluffs in sharp angles and all fluming and filling was avoided. The fall of 3 to 4 feet per mile was also great. Two thirds of the expense of maintaining and improving these canals has gone to straighten the channels and check the too rapid flow of water in order to save the banks.

TESTIMONY OF IRRIGATIONISTS.

An illustration of the first irrigation is to be seen in the experience of Henry Devotea, an original colonist, who states that:

> I came to Greeley with $2,000 and lost it in three years because I did not know how to run my ditches. I tried to do it by my eye, and to get my water up hill. Some of the men in those days tried to run water across a swag without diking. After

this experience I bought a level and ran my ditches properly. A good deal of conceit was taken out of me by that three years' experience. I afterwards learned it was a great deal better to have a proper survey made. My best crop of wheat has been 3,200 bushels from 100 acres, and my lowest average about 15 bushels per acre. The reason of that low yield was that I planted wheat after wheat for several years; this depleted the land. Crops must be alternated to get good yields. Alfalfa always improves land, acting as a fertilizer and breaking the subsoil. My best yield of potatoes was 250 bushels or 137 sacks per acre, but I have gone as low as 75 bushels per acre. I kept the average of my crop from 1873 to 1880; during that time I had but one total failure from causes I have described. The average yield was 20¼ bushels of wheat to the acre. In good years it will run 27 and 30 bushels. It must be remembered in making these averages that I had some old wheat land in every crop, and that runs the figures down. When the crops are rotated the average should be 30 bushels.

When I first came here we had to go 130 feet to get 3 feet of water in a well. Now I have a well 51 feet deep with 30 feet of water. We strike sandstone and slight seams of coal, but the water will stand on the average at 10 feet from the surface. The water level is now within 5 feet of the surface in many places, and in some low spots during irrigating season it will come within 10 inches of the surface. My crop for 1890, minus seed, was sold for $4,500, costing to raise $800; my 100 acres returned me, then, a net profit of $37 per acre.

Mr. Devotea lives under community ditch No. 2, and was one of the constructors thereof.

Dr. **GULEMUS LAW**, a gentleman who has given much study to irrigation in and around Greeley, said that the early mistake in Community Ditch No. 2, aside from its want of capacity to carry water, was its crooked course, and consequently it cut out on one side and silted on the other at every turn. But, in a very few years practical experience taught that we could get a great deal more water through a straight ditch than a crooked one; that it was better to go through a ridge than around it, and to dike across a depression. Another fault was that the ditch was constructed at too great a slope per mile. A ditch of 3 or 4 feet per mile will cut. Two or 2½ feet is ample, and the ditch should be of sufficient size to get the benefit of the pressure of the water. The grade should not vary because if it is greater at one point than another it will cut and silt. If it is relatively straight and of an even grade and made smooth one will not have much trouble with silting; but if it is 2½ feet in one place and 4 feet in another it will cut and silt.

Land to be valuable for agricultural purposes must have a substantial subsoil under it. Sand and gravel substratum requires an enormous quantity of water to irrigate.

Dr. Law was of opinion that if the land around Greeley was properly prepared and sufficient seed used, the yield would be increased 50 per cent; at present the plowing was too shallow. Every foot of land intended for potatoes should be subsoiled in order to get best results. And the reason that potatoes do so well on alfalfa land is simply that the subsoil is thoroughly broken by alfalfa roots. An experiment on a square rod of land properly prepared for potatoes yielded at the rate of 578 bushels per acre.

E. H. BENTON, a very successful horticulturist, under the No. 2 canal, asserts that there is a strip of country running 20 miles east of the mountains and 150 miles along the range not favorable to fruit, because there are a great many still days, during which the weather will get quite warm as early as February or March, and then turn suddenly cold after the sap has started. The soil is, however, good for apples and plums. If laths were woven together with wire and placed around the tree in the shape of a box, this would be overcome.

His plan is to grow low crops, such as beans, cucumbers, beets, squashes, melons, and orchards, and then mulch the trees, and do it with manure so that the frost shall not touch the roots, and leave that on until the 1st of May. Raspberries and strawberries in the orchard have a very good effect upon the trees.

Another thing is to irrigate as late as possible, into November, even if the water freezes in the ditches; then mulch to prevent frost. Last year he raised 75 sacks of potatoes in his orchard. Cabbage would do well, but no grain should be put in under any circumstances. The trees should be deeply set, about 6 inches deeper than in the nursery. An important essential in tree planting is that every root should be trimmed smooth, so that when they are planted new roots will spring out immediately. If you put a tree in with mangled and split roots none will start. It is a *sine qua non* that every root should be trimmed with a knife. Alfalfa is the crowned king in this region; a crop of it turned under will do more for the land than any other fertilizer. The Ben Davis is the best apple for this region. The Wolbridge and Wealthy also do well.

M. J. HOGARTY came with the colony, and thinks the duty of water has doubled. On large farms one-half an inch will do what an inch would hardly do formerly, but a man must have the opportunity to practice economy. For instance, an 80-acre water right is supposed to be a cubic foot per second, but half that amount is now sufficient provided there is no waste.

Last year his crop was:

Thirty acres of potatoes at 75 sacks to the acre, at $1.40 per sack	$3,370.00
Fifty acres of wheat averaged 41 bushels, at $1.33 per cwt	1,635.90
	5,005.90

an average from two staples of a little over $62.50 per acre gross at an expense as follows:

Water right	$16.00
Hired help (one man for seven months and board)	315.00
Threshing (5 cents per bushel)	102.50
Taxes	55.00
Sacks and twine	155.00
Three horses at 50 cents per day	175.00
	818.50

The total expense of farming on irrigated land is therefore only slightly over $10 per acre. The cost of application of the water is included in the cost of hired labor. The system that offers $50 net profit from potato and wheat land should be carefully studied by every farmer.

C. O. JENNINGS in 1887 paid $37.50 per acre for 80 acres. He has 25 acres in potatoes, 35 acres in wheat, 8 in alfalfa, and about 12 in trees.

Last year's crop was 325 sacks of wheat, worth $1.46 per sack; 1,200 sacks of potatoes at $1.60 per sack; and 24 tons of alfalfa, which he fed to stock. The return therefore from two field crops, 60 acres, was $2,394.50, or an average of $39.90 per acre.

His estimate of cost on a 6-acre tract is as follows:

Wheat:	
Putting in	$3.50
Price of seed	5.40
Irrigating twice	4.00
Cutting	7.50
Stacking	2.50
Threshing	10.02
	32.92
Cost per acre	5.48

Potatoes:	
Breaking (not alfalfa)	$9.00
Seed	27.00
Irrigating (three times)	6.00
Sacking, digging, and hauling, at the rate of 50 sacks per acre, at 25 cents per sack	81.00
	123.00
Cost per acre	20.50

He has five very thrifty cherry trees, but has never sold any fruit.

D. H. Gale farms sec. 9, R. 65, T. 6. On the east side of his farm in Lone Tree Creek there is enough seepage water flowing to irrigate 80 acres. Previous to the introduction of irrigation this creek was dry except in flood time. Six miles above his place where it is too high for seepage there is no water yet.

At Fort Collins the Cache la Poudre will be dry, and 26 miles below that place there will be water enough to fill a ditch carrying 25 cubic feet per second, the water all coming from seepage.

In this connection, Mr. J. C. Swann, who bored a well on ex-Gov. Eaton's place, half a mile north of Eaton and about 9 miles north of Greeley, on N. E. ¼ of sec. 36, R. 66, T. 7, stated that at 23 feet below the surface is a stratum of gravel 65 feet thick, of which one-half the cubic contents is water. An actual test shows that a cubic foot of the stratum yields one-half a cubic foot of water. Before the construction of the Larimer and Weld canal this gravel was dry.

Mr. Gale continuing said that on his place exclusive of stock he raised 300 acres of alfalfa, 45 acres of potatoes, 93 acres of wheat, and 30 acres of oats. His expense of cultivation was about $3,000 and he cleared gross $11,000. The first cutting of 25 acres of alfalfa measured 90 tons in the stack. He has eight water rights from Larimer and Weld.

H. C. Watson, president of the Greeley Mercantile Company, gave the following statistics of crop shipments during 1890:

> Two thousand five hundred carloads of potatoes, averaging 400 bushels to the car, making 1,000,000 bushels, were shipped from this depot. This crop was raised under No. 2, Larimer and Weld and Loveland and Greeley ditches.
>
> My books show an average of 25 bushels of wheat to the acre. One hundred and fifty carloads of cabbage were shipped, at an average price of 60 cents per cwt. Two acres of cabbage on the Loveland and Greeley ditch sold for $325.92. This was not in a garden. Had it been under garden culture the yield would have been from 20 to 40 per cent higher.
>
> Mr. Solomon, of Denver, rented, for a proportionate share of the crop, 160 acres, of which 110 acres were cultivated. His crop rent was $693, representing one-third of the corn and one-fourth of the potatoes. This was a small crop.

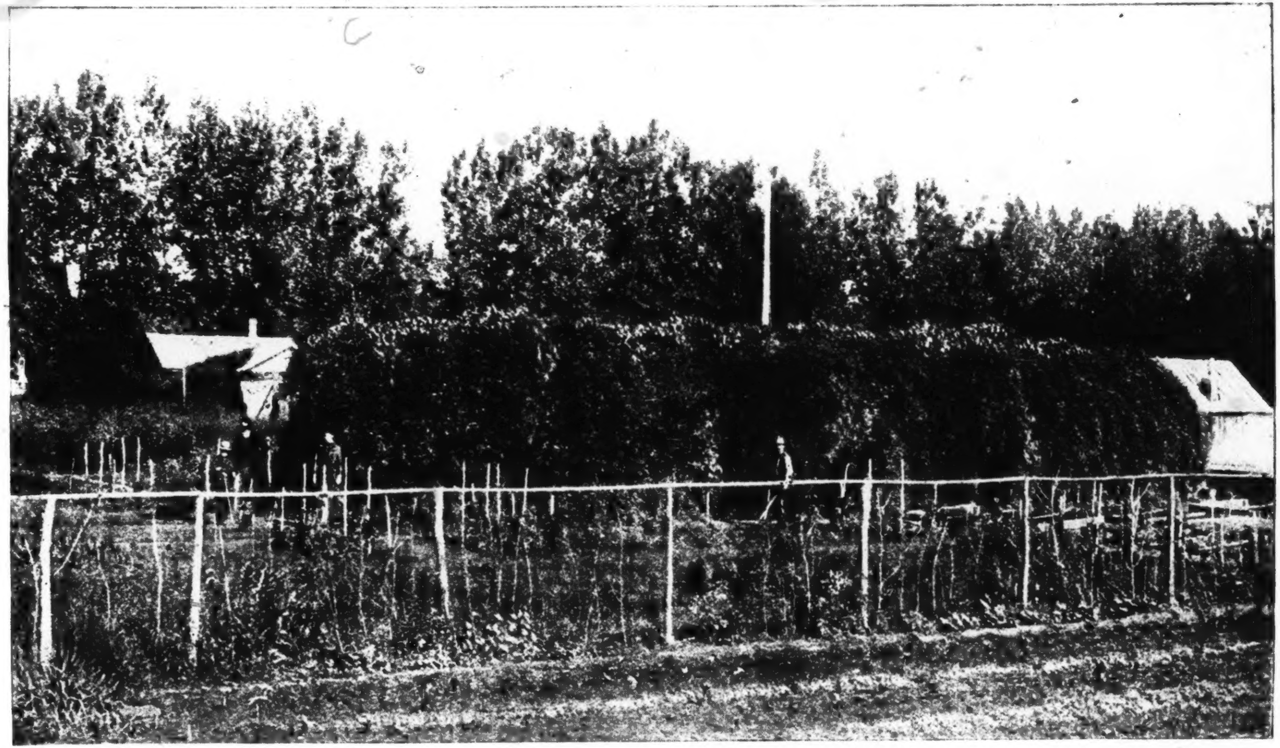
John Leavy is a horticulturist, and selected an acre tract as his allotment from the Union Colony, asserting that "1 acre of ground is all a man can properly cultivate as a gardener."

The open-ditch system is the best for garden irrigation; flooding is bad for it puddles the land. The great trouble with most irrigation is the use of too much water; one-fourth the amount used in many instances judiciously applied would produce better results. Irrigation is best practiced under intense sunshine.

The rule should be to water thoroughly, *when you do irrigate*, but do so as seldom as possible because water lowers the temperature. A little personal experience is the only guide when to apply water.

In 1885, a cauliflower raised on Leavy's place, took the prize at Peter Henderson's exhibition. It weighed 11¾ pounds, when trimmed. He also exhibited another of 10½ pounds. Cauliflower should average 75 per cent of the crop weight of cabbage. A piece of ground that will produce 40,000 pounds of cabbage should yield 30,000 pounds of trimmed cauliflower. The Erford variety seems to prosper best in this locality.

Celery requires a still higher cultivation than any of the above, but we can raise here and in similar climates in the arid region as fine celery as anywhere on earth. It is essentially an aquatic or marsh plant, and about the only one you can not injure by excessive irrigation, and a very safe crop for the inexperienced irrigator. It wants plenty of water. The best method is a modified form of the old system of drainage.



Garden by Irrigation, Greeley, Colorado, 1890.

An open shallow drain, 5 inches deep, is first constructed on the level on which is put a coat of well fermented manure to the depth of 2 inches. This manure should be thoroughly incorporated with the soil, and then you place your plants out at the usual distance apart, which is perhaps from 6 to 7 inches. Then you have only a trench of 3 inches, which gives you the advantage of—

(1) Flowing plenty of water on it.
(2) Excessive irrigation does not injure it as it is a marsh plant.
(3) It facilitates "earthing up."
(4) By the month of September the celery roots are 2 feet out from the stalk.

By this modified trench system with the plants set out on the single-row plan which is best adapted for horse culture, 18,000 to 20,000 heads of matured celery should be grown. The rows should be 4 feet apart, and the plants in any single row not to exceed 6 inches.

Beets of the mangel-wurzel variety thrive here very well and should yield from 20 to 30 tons per acre. Onions should be raised by transplanting, and the ground should not be prepared but a day or two before you are going to plant. Over 1,500 bushels and often as high as 2,000 bushels can be raised by that plan and a proper attention to irrigation.

In all crops it is not broad acreage, but labor, that tells upon the yield. The experienced cultivator will get more out of his garden than the broadcast farmer. Peas and beans do remarkably well and 30 bushels to the acre is the average here for the white beans. Radishes and all the root crops will do well. Strawberries should be irrigated through the rows, and should yield according to the cultivation from 2,000 to 5,000 quarts.

At a meeting of the board of directors of the Cache la Poudre Irrigation Company, at which were present S. A. Bradfield, H. M. Williams, J. S. Newell, O. H. Adams, Henry Devotea, and George M. Jacobs, the following statistics of expenses on an 80-acre tract were given as the agreement of all after discussion:

Hired help on an 80-acre tract	$320.00
Potatoes cost per sack	.20
Threshing	.05
Water tax main ditch, 1891	16.00
Lateral tax	12.00

Per acre yield under No. 2.—Forty-five thousand pounds of cabbage per acre have been raised by unskilled men on bottom lands, around Greeley, but any man who raises less than 45,000 to 55,000 pounds of cabbage is no gardener.

PAYMENTS MADE BY ORIGINAL COLONISTS.

Each of the Union colonists paid $150 to the colony funds, $5 of which was in the nature of an initiation fee, intended to cover the expenses of the locating committee. For this payment of $150 each individual was entitled to a selection of land as laid out by the officers of the colony.

1. A block, or a 5-acre lot immediately adjoining the town, with water in perpetuity.

2. A 10-acre tract a little farther away, or a 20-acre tract still farther away, or 40 acres at the extreme limit of the colony. The latter was the largest amount of land, with water, that the colony gave in satisfaction of a certificate. Those who desired larger amounts of land availed themselves of the contract made by the Union Colony with the Denver Pacific Railway and Telegraph Company, and their lands were commonly called railroad lands, or they filed on Government lands under the

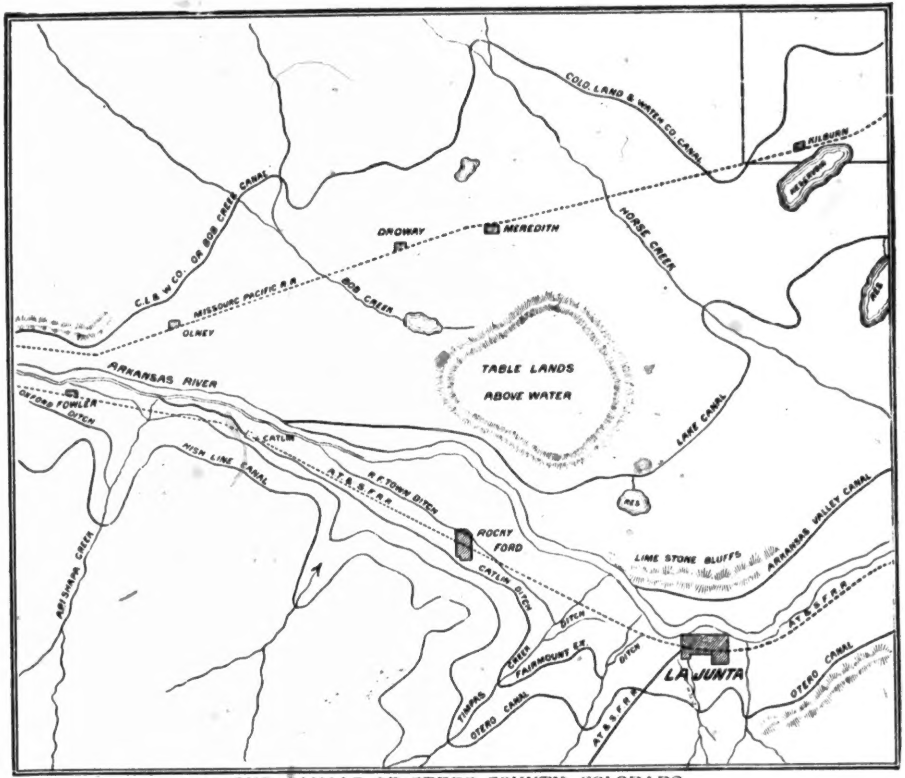
homestead or preëmption laws. To the latter class the Union Colony granted the right of water for 80 acres of land, inclusive of the land taken from the colony.

THE PHREATIC SUPPLY.

The first well in Greeley was dug at the intersection of main and Monroe streets, and water was struck at 22 or 23 feet in a gravel stratum. The second well was dug by Henry T. West, on a lot in the second block to the south, and water obtained at 25 feet. In each case there was about 3 feet of water. After the irrigation season of 1871, in the fall, instead of 3 feet of water there was 12 feet in both wells, and the water had become hard. For ten years past the water has not been potable, but has increased in depth to 19 feet. In connection with this fact, eight or nine years ago the cellars in the western and souhwestern parts of the city began to fill with water, necessitating the building of a drainage sewer along the main street. It is an open-jointed pipe-sewer about 2,000 feet long, with brick chambers for manholes, carrying 400 feet. On the 10th day of May, 1891, when this sewer was examined by the agent of the Department, there was more than sufficient water running to afford a water right for 80 acres, or about a cubit foot per second.

J. C. Swann, of Swann Bros., artesian-well borers, states that—

> The record of the Loveland well at Loveland is 30 feet of surface formation above bed rock, composed principally of gravel filled with water. The bed rock is blue slate and sandstone, the slate of great thickness and the sandstone less. At 150 feet we found a vein of brackish water in sandstone which rises to within 60 feet of the surface. Below that no water was encountered until the depth of 1,365 feet. At this point the true artesian stratum is reached. It is a close-jointed sandstone, 30 feet thick. Below it no further sandstone is reached until the 1,600-foot level, when there is another strata of close-grained sandstone 5 feet thick, containing petroleum in small quantities.
>
> Below this point, 2,400 feet below the surface, it is sandy shale devoid of water.
>
> The test-well drilled in Lincoln Park, Greeley, to a total depth of 2,140 feet, is about as follows:
>
> 32 feet soil and gravel to the first bed rock, the lower 24 feet of this stratum being filled with sheet water in about the proportion of one-half gravel to one-half water. Before irrigation the bed was dry to a depth of 27 feet. This gravel bed is universal in the valleys of the Poudre and South Platte, varying from 1 to 5 or 6 miles wide in most places to 10 miles at the greatest width at a point near Stirling.
>
> On the South Platte, at any point north of Denver to Stirling, Colo., it is a fair estimate to say that the saturated gravel will average 40 feet deep, and throughout the entire distance would not be less than 3½ miles wide. This body of gravel has always been saturated. It is a fair presumption to say that this represents a lake of water having an average depth of 20 feet and covering a territory of the dimensions above named, or 462 square miles. The source of this supply is the water that sinks from the surface flow of the South Platte.
>
> The same is true of the Poudre Valley within the limits of its extent. This valley is one continuous bed of shale to a depth of 1,165 feet, overlaid with soil and gravel, and with a substratum of 30 feet of close-grained gray sandstone, the source of artesian water; but the flow only amounted in the test well at Lincoln Park to 35 gallons per hour, which has now entirely ceased, and pumping has been resorted to in this and other wells. Below that to a depth of 2,140 feet shale is encountered all the way devoid of water. This is the deepest drilling in the Poudre Valley. Six other wells have been drilled to the water-bearing stratum in Greeley. There are nine wells, all told, in this basin, of which the one at Loveland and the one at Evans still continue to flow, but even they are not true hydrostatic flows.
>
> In surface irrigation for general field crops there is no doubt but that it requires six times as much water in spreading it over the land as the wants of the crops require. This is true in a general way of all field crops except corn and potatoes.
>
> We have but three calendar months here free from frost—June, July, and August. From the time frost ceases in May until it returns in September will be about one hundred and twenty days. Therefore what seems to be our misfortune, namely, our aridity and our intense sunshine, is all that makes this country inhabitable. Our cereals and other crops are largely composed of carbon, to produce a pound of which, in the shape of a growing plant, calls for the expenditure of heat energy sufficient


COLO. LAND & WATER CO. CANAL
KILBURN
RES
C.L & W CO. OR BOB CREEK CANAL
DROWAY
MEREDITH
HORSE CREEK
MISSOURI PACIFIC R.R.
BOB CREEK
OLNEY
RES
TABLE LANDS
ABOVE WATER
ARKANSAS RIVER
OXFORD FOWLER
DITCH
CATLIN
LAKE CANAL
HISH LINE CANAL
A.T. & S.F.R.R.
R.F. TOWN DITCH
RES
ROCKY
FORD
LIME STONE BLUFFS
ARKANSAS VALLEY CANAL
ARISHARA CREEK
CATLIN DITCH
DITCH
A.T. & S.F.R.R.
CREEK
FAIRMOUNT CR.
DITCH
LA JUNTA
TIMPAS
OTERO CANAL
A.T. & S.F.R.R.
OTERO CANAL

THE CANALS OF OTERO COUNTY, COLORADO.
Illustration of the progress of irrigation in the Upper Arkansas Valley.

to raise the temperature of 14,500 pounds of water 1° F. scale. The intensity of our sunshine and the almost constantly cloudless condition of our skies enables growing crops to be matured in much less time than in a humid climate. This is the explanation of our growing and maturing general crops here at all, and the explanation of the value of irrigation in an arid climate over farming in a humid climate. My own opinion is that materially better methods of distribution will come into play, and that water will continue to increase its value as an economic factor until it will never be wasted as now in Seeleys Lake and elsewhere in this region; but that combined efforts will more and more increase the duty of water even to the adoption of a system somewhat similar to the Paris street-sprinkling plan.

Irrigation as now practiced is crude, and the waste of water enormous, but its scarcity and its constantly increasing value will lead to better conservation. The general use of perforated pipes will probably be the first step.

IN THE ARKANSAS VALLEY.

In illustration of the lessons this work of coöperative farmers have afforded to irrigation organizers in Colorado, the following account of a commercial enterprise will be read with interest:

The Colorado Land and Water Company are engaged on works that promise the reclamation of a large proportion of the Arkansas River Valley and plains lying east of Pueblo. Already a considerable acreage is under high cultivation, and the special fruit and vegetable crops that are raised at Rocky Ford and other points along the line of these canals have become quite famous for quantity and quality.

The enterprise has attracted investigation, not only because of its magnitude and the success obtained in opening a large area to cultivation, but because of construction characteristics, especially by way of open plains reservoirs. These are more numerous than on any other canal system in the State, and, as a result, the storage facilities obtained are very large.

Reservoir No. 1 covers, when filled, nearly 700 acres, and 16 feet can be drawn off. Reservoir No. 2, when filled, covers 2,100 acres, and 14 feet can be drawn off. Reservoir No. 3, when filled, covers 21,000 acres, and 40 feet can be drawn off. Reservoir No. 4, when filled, covers 5,600 acres, and 22 feet can be drawn off. The first two of these reservoirs are in Otero County, and Nos. 3 and 4 in Kiowa County. The total acreage covered is 29,500, and the average depth is over 20 feet.

The original survey of this canal was made about 1885 by H. R. Holbrook, C. E., of Pueblo, for a company called the Pueblo Land and Canal Company. This survey covered the ground occupied by the present canal, and located the large reservoirs at the eastern terminus of the present ditch. E. S. Nettleton (chief engineer of the Artesian and Underflow Investigation), after examination, stated that the largest reservoir would irrigate, when filled, 200,000 acres of land.

The Colorado Land and Canal Company was afterwards organized by Colorado Springs parties, who re-surveyed the line of canal and did some construction work in April, 1889. Early in June, 1890, this present company bought out the interests of the Colorado Springs people, and continued the work of construction actively, completing the canal to its present terminus at the crossing of the Missouri Pacific Railroad, east of Horse Creek, a distance of about 74 miles.

The headgate is on the north side of the Arkansas River in the NE. ¼ NE. ¼, sec. 10, T. 21 S., R. 62 W., in Pueblo County, Colo., 426 feet east from the section line. The canal is 30 feet wide on the bottom, not less than 8 feet deep, with side slope of 1 to 1 foot and a fall of .056 feet per mile, except for the first and second miles, which are 4.22 for the first and 2.64 for second. The computed carrying capacity with 7 feet of water running is 756.28 cubic feet per second. At the intersection of

Boom Creek there is a waste way 40 feet wide constructed to the river. The first flume, 700 feet long, is 12 miles from the headgate over Krammer Creek. The creek bed is shifting sand, ordinarily dry on the surface but yet draining 50 miles of country. This flume affords passage for storm water under the canal.

It rests on oak-pile bents or supports for the flume, 16 feet apart, 7 and 8 piles to the bent, capped with 12 by 12-inch timbers and braced against lateral pressure of wind or flood water. The floor joists are 6 by 12 inches and 16 feet long, set at 2½ feet from center to center, covered with 2-inch plank laid transverse to joints. The side posts of the flume are 6 by 8 inches, 9 feet long, well braced against heavy timbers resting on the projecting ends of the bents, and are lined inside with 2-inch planks to a height of 8 feet.

Automatic waste gates are set in the south side of the flume, of a combined width of 32 feet; shut-off gates are also put across the flume just below the waste gates, by which the water can be entirely directed from canal in case of accident to banks. Two hundred and fifty thousand feet of Mexican timber have been used.

The inside width of head gates is 38 feet 5 inches, and inside length 73 feet 6 inches. There are twelve check gates averaging about 2 feet 7 inches, and 8 feet 4 inches high. In connection with these head gates there is also a waste or spill way with thirteen gates. These are a little wider and the same height as the check gates, and in connection with the waste way there are gates that can be opened from the north to carry off the flood waters of Haines Creek at that point. These gates, opening to the north, are six in number and are about 2 feet wide and 4 feet high, and have proven a great success. The controlling gates are raised 12 inches above the canal floor so as to allow the sand to scour out through the waste gates. This feature, combined with fall for the first mile of 4.22 feet, keeps the channel well scoured out.

The canal is divided into 100-feet stations and all flumes are constructed substantially as in the foregoing description. This company completed the canal under contract with the State of Colorado, from which it has bought and leased the alternate half sections of State land lying under the line of the canal. Title has so far been obtained, by work done, to 72,000 acres, that is 36,000 acres purchased and 36,000 acres leased. Under this contract the State retains ownership to one-half of the entire tract of land, which is leased to this company at a nominal figure, and will eventually realize the difference between the value of raw and cultivated land. The company is compelled to apply water on all of this leased land in order to make good their title and the State agrees that in any future lease or sale to other parties the water shall be treated as an improvement to the land, the same as fencing, building, or other improvements are, as provided for by law. In disposing of the purchased lands an equal amount of leased land is given each purchaser at a very small rental and the improvements made thereon are to be purchased by any subsequent lessee or vendee at their full value.

The intention is to run the canal all the year round when safe to do so, storing the water of the Arkansas River in the basins. This can be done in large canals, as the water continues to run under the ice without disturbing the banks. The unused waters of the Arkansas River flowing to waste in the fall, winter, and spring, will be stored when not needed for irrigation, and also all flood water. The prevailing rule is for canals to "shut down" in winter, so as to prevent breaks. In this way the waters of the area served are of course allowed to run to waste.

The Arkansas system proposes the opposite course. There is very little artificial embankment on our reservoirs, and the cost not much compared with the magnitude of the scheme and the results obtained. The cost of the entire canal together with land purchased and leased has been:

Cost of canal now built	$376,000
Cost of reservoirs and extension of canal into them with necessary laterals cut from the canal, estimated at	124,000
	500,000
Cost of 36,000 acres of purchased land	90,000
Cost of 36,000 acres of leased land	10,000
	600,000

The canals with its resevoirs, will fully irrigate 300,000 acres, which figure, it is claimed, by economy of service, may be materially increased.

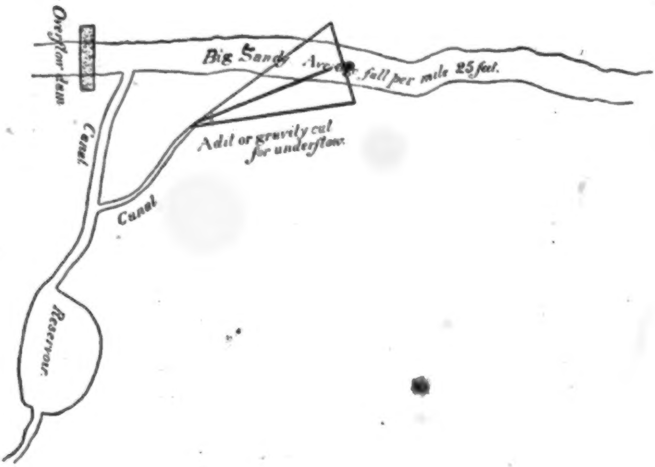
The service of water is generally 1.44 cubic feet per second for 80 acres. This corporation has adopted 1.08 cubic feet, which, according to the best authorities, is sufficient for Colorado lands; in fact the tendency is to restrict the amount to 1 cubic foot for 80 acres.

The use of water is restricted to 100 days' continuous delivery or the irrigation season, which is fixed by the contracts to begin April 15 and end September 30. This service is an innovation, as the rule has been to fix the period of continuous delivery "as during the irrigation season," which under Colorado statutes begins April 1 and ends November 1. The motive in the decrease of forty-five days is to prevent waste. Practically the delivery is not continuous, as no man can use water every day. In northern Colorado, where the finest grapes have been raised, the crop seems to be in direct ratio to the scarcity of water. That a much less amount of water is required has been established by experience there so that the secret of success is using the water at the proper time. The ditch and reservoir system, while under the same management, are under different companies and any one desirous can exchange his water; for instance if a man uses but sixty of his one hundred days he may run his unused water into the reservoirs and thus get credit for water outside of the irrigation season. A water right costs $10 per acre or $800 per 80-acre water right, and an annual rental never to exceed $16 per water right for maintenance and repairs, or 20 cents per acre per annum. This is about the rate on community ditch, No. 2, at Greeley, and is based upon the experience of that enterprise.

Besides the Colorado Land and Water Company Canal, also known as the Bob Creek Canal, the Lake and the Great Arkansas Valley canals take water out of the Arkansas River on the north. The Highline, Otero, and Catlin canals and the Oxford and Rocky Ford ditches distribute the water on the south. The staple crops are wheat, corn, and alfalfa. There is a considerable area in orange orchards, and acres are devoted to melons, yielding large returns. The area of reclaimed land in Colorado, while being sensibly increased by the completion of such large canals as the Otero and Colorado, is making equal, if not so apparent, progress in the reclamation of small areas; on the Big Sandy, for instance.

During February and March, 1890, there was a dam thrown across Big Sandy Creek, on the Kansas division of the Union Pacific Railway, near Lake station, about 93 miles from Denver. The structure was 1,100 feet long, 72 feet wide on the bottom, 16 feet on top, and 12 feet high. A ditch therefrom was 6 feet deep and 60 feet wide on the bottom, carrying water to a reservoir about 1 mile distant. The dam broke away on the 11th day of August, 1890, but will be repaired under better construction. The volume of water during that flood was 5 feet deep and 640 feet wide. The reservoir will contain 968 acres, at an average depth of 12 feet, and will irrigate from flood water alone 17,500 acres of land. The underflow may also be utilized to irrigate as much more. The water-bearing sand, from which the underflow is gathered at no point more than 12 feet below the surface, is 1½ miles wide and of unknown depth.

The general plan of the works is as follows:


Overflow dam
Big Sandy
Average fall per mile 25 feet.
Adit or gravity cut for underflow
Canal
Canal
Reservoir

The Howard Ditch, on Box Elder Creek, about 35 miles east of Denver, cost $400, develops 204 cubic inches of water, or more than 6 cubic feet per second. Over 300 acres are now cultivated from it. If properly developed 15,000 acres could be irrigated from this source.

The Gusbueck Ditch and Reservoir, 70 miles southeast of Denver, in Elbert County, cost $600, it develops 200 cubic inches of water, and irrigates 300 acres of land. At Agate, on the Kansas and Pacific Railroad, the drainage of 45,000 acres during a rain of 30 minutes filled a reservoir of 158 acres, 18 feet deep over the central 60 acres. Seventy acres of the land irrigated from the reservoir produced more than 200 tons of millet and sugar corn.

Torrential rains occur invariably in July and August, doing the least good to the crops. These storms amount to more than half the rainfall, and pass over the land with but little if any percolation wherever the natural grasses remain. Whenever any considerable bare spot occurs the ground after rain will be moist for 15 or 20 feet below the surface. Wherever there is grass the rain will not sink more than 6 inches.

These instances afford an idea of the facility of reclaiming small tracts, which in the aggregate would amount to 30 per cent of the land that can be reclaimed in Eastern Colorado. In a line west from Agate, towards Denver, there are 70,000 acres that might cheaply be reclaimed from the drainage of the divide between the Arkansas and Platte rivers.

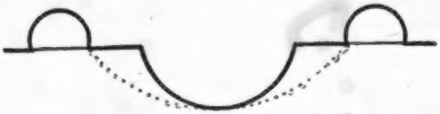
Mr. H. P. Holbrook, civil engineer of Pueblo, Colo., is of opinion that not one-tenth part of the high-water flow of the Arkansas River is utilized. The numerous canals and ditches will remedy this to some extent, having the effect of storage reservoirs. They also fill the ground with water, which slowly percolating back to the river preserves a more equal flow throughout the year. The irrigated land thus acts as a reservoir in which is preserved for future use all the water not lost in the first evaporation and the nourishment of the crops.

IN THE SAN LUIS VALLEY.

A mountain park, the lowest level of which is 7,000 feet above tide-water, 200 miles long by an average of 40 wide, embracing in its area the arable portion of Rio Grande, Saguache, Costilla, and Conejos counties, is known as San Luis Park or Valley. It is walled in by the Sangre de Cristo Mountains and the main range of the Rockies. On the east the Sierra Blanca and the Spanish Peaks rise at the highest point to 14,464 feet above the sea, and on the west towers the Continental Divide. An enormous drainage is precipitated from the snowy ranges through some twenty-three water courses, while many small streams start into the valley whose flow is quickly absorbed by the arid soil. They are either lost to sight, form quagmires or cienagas. The Rio Grande River enters from the west, running east to about the center and then south to the outlet of the park. It forms the principal source of supply for the large canals. The bed of the Rio Grande is now almost along the highest ground or divide of the valley, and its waters may be taken out with little difficulty to the lands on both sides of the river. The geologic evidence is however apparent that at one time this river turned north in the form of a huge horseshoe, and ran through the trough of the valley. Agriculture by irrigation in San Luis Valley is carried on under the Mexican, Mormon, and American plans. The first is unimportant, and the second only of small area, principally around La Jara.

There are more than five hundred ditches, large and small, in the valley, the principal of which are the Empire, San Louis, Rio Grande, and Monte Vista. The Empire is the oldest of the large canals, and when all possibilities are taken into consideration, may irrigate 300,000 acres. On August 11, 1891, one hundred and sixty-four water rights had been sold to individual farmers, each of which will irrigate 80 acres. The canal is 80 feet wide on the bottom, with a slope of sides of 3 feet horizontal to 1 foot vertical, and 6 feet deep, with a fall varying from 20 inches to 2½ feet per mile, according to the character of the soil. This canal takes water to the land on the south side of the Rio Grande. It is 40 miles long, has eight main laterals of an average bottom width of 10 feet and an aggregate length of 100 miles. The San Luis is the next large canal, and it is 40 feet on the bottom, with a slope of sides of 1½ feet horizontal to 1 foot vertical, with a 5-foot berme or embankment on each side, 6 feet deep, with a fall of 2½ feet to the mile.

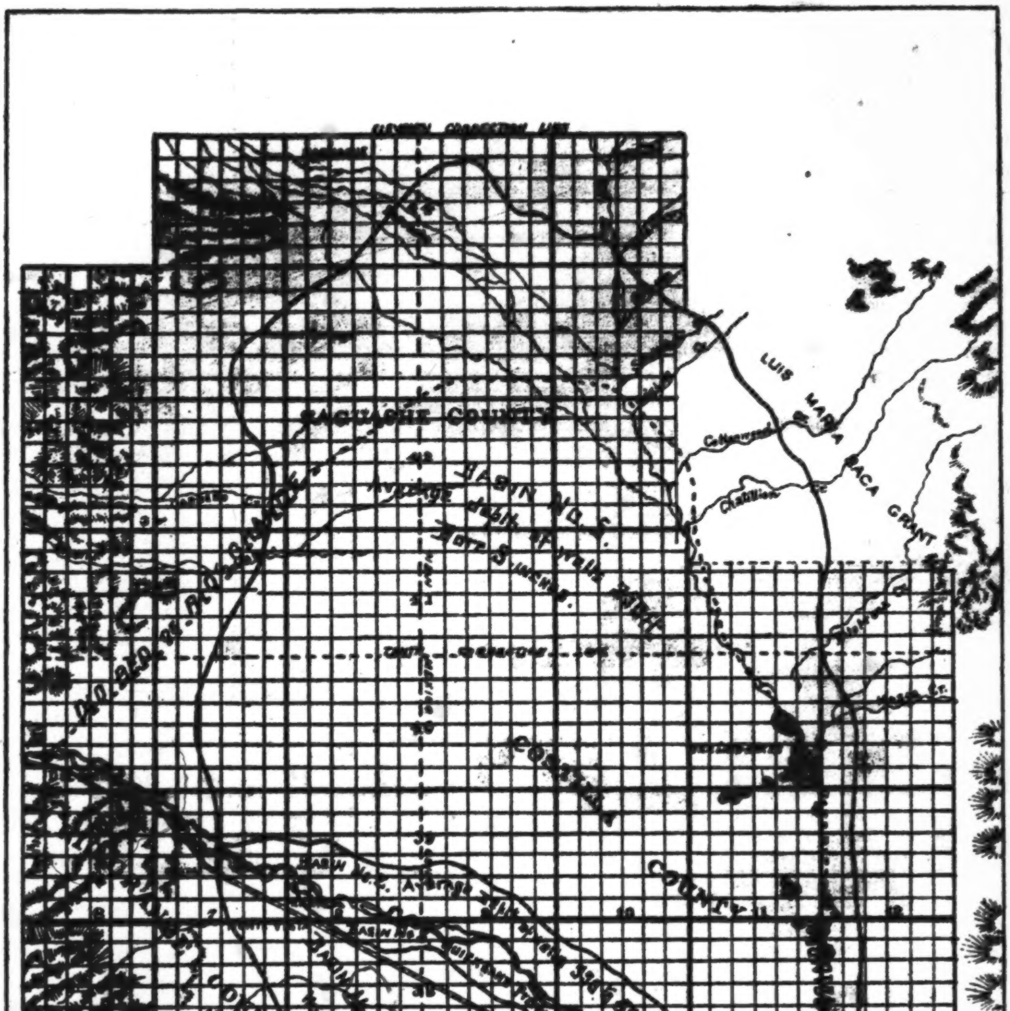
When first constructed the solid lines in the above cut represent the appearance of the ditch and berme; the dotted lines the appearance and size of the ditch after a few years' use and the sharp contours left by the excavation have been worn away. The main canal is only 5 miles long, and it then divides into two laterals each 15 miles long, 20 feet bottom width, 4 feet deep, of similar construction to the main ditch, but with a fall of 5 feet to the mile. The duty of this canal is estimated at 100,000 acres.



These two large canals are part of the great system of irrigation known in Colorado as the Henry canals, and were organized and built under the supervision of Mr. T. C. Henry, C. E. The companies control in the San Luis Valley, by purchase and lease from the State of Colorado, 155,000 acres of land on both sides of the river. This is held from the State on condition of improvement by irrigation.

The Del Norte or Rio Grande Canal was the next taken out of the river. It has an 80-foot bottom, 2 to 1 foot slope of sides, 6 feet deep, and 5 feet fall per mile. There are 80 miles of main ditch, and 100 miles of main laterals, which will irrigate 300,000 acres. Mr. Walter H. Graves was the engineer. The Monte Vista Canal is 40 feet on bottom, 5 feet deep, 2 to 1 slope, and 2½ feet fall to the mile. It is 40 miles long and has 60 miles of main lateral, with about 200 miles of distributing laterals, and will irrigate 150,000 acres. On the first of June, 1891, twenty-five 80-acre water rights under the Monte Vista, and one hundred and eleven 80-acre rights under the Rio Grande Canal had been sold to individuals. These canals are owned by the Travelers' Insurance Company. Besides the water rights sold to irrigators the company cultivates under these ditches, 23,560 acres of land in eight farms, of an average size of 2,945 acres, and varying from 7,640 to 160 acres. Under the Henry canals about twice this amount of land is cultivated in four farms, the largest of which is the Empire farm of 19,000 acres. The bulk of cultivation on these immense tracts is done by machinery, and the yields are not so large as on the smaller farms individually owned. The cultivators live in bunk houses, or shanties, and the scene on one of these corporation farms is very different from that presented in the greater part of the irrigated region, where each oasis of reclaimed land is ornamented by the tasteful homes and beautiful foliage of the door yards of the farmers. The corporations offer the settler the improved land with a permanent water right, at prices varying from $15 to $35 per acre. This farming is the direct growth of the law of Colorado, which requires the owners of lands purchased from the State not only to build the ditches to cover them with water, but to actually cultivate either themselves or by their agents all the land purchased or leased before an absolute title is effected.

In many parts of the San Luis Valley, since irrigation has been widely practiced, large areas of land from which crops are raised receive their water by means of what is locally termed "sub-irrigation." The subsoil under these tracts is a stiff adobe, easily and quickly saturated with water, but very slow to transmit it. This brings the water table very near the surface in some places, and no water is applied to the surface at all. In other areas small farm laterals are run along the highest part of the land to be irrigated, and the water will seep for


ELEVENTH CORRECTION LINE
SAGUACHE COUNTY
BASIN NO. 2
COSTILLA COUNTY
CONEJOS COUNTY
BASIN No. 1
LUIS MARIA BACA GRANT
SANGRE DE CRISTO GRANT
Rio Grande River
MANASSA
EIGHTH CORRECTION LINE

ARTESIAN WELLS
—Basin—
SAN LUIS VALLEY.

1,000 feet, giving ample sustenance to the crop. Sub-irrigation is cheap and lands susceptible to its influence are among the most valuable of the San Luis Valley.

THE SAN LUIS ARTESIAN WELLS.

There are now about 3,700 flowing artesian wells in the San Luis Valley, but of these only three are deep wells of large bore. Two are 6-inch wells at Alamosa and the other is an 8-inch bore at Moffat. A correspondent describes the last-named well as spouting a "stream like a stovepipe, 10 feet high, without a break." This well was struck since the investigation made by this office, and the above is not known to be a fact. The two 6-inch wells at Alamosa flow about 8 inches above the 6-inch bore, but if confined to 2 inches will throw a stream 45 feet high. The strata encountered in all wells is generally—

Soil	3 to 6 feet
Sand and gravel, alternate layers	20 to 50 feet
Blue clay and sand, alternate layers	to water

Besides these wells mentioned there are in the valley about 25 wells of from 3 to 4 inch bore and not more than 800 feet deep, generally about 700 feet. Only about 10 per cent of the total number of wells penetrate to a depth of 700 feet, and barely 15 per cent go down 400 feet. No rock strata has been encountered, but the clay is of a very hard, close texture, the grain of which is so fine that it can be bitten through with the teeth without detecting the slightest grit. The sand is, however, very sharp. The best flow, except in the instances of the three deep wells named is from a stratum at about 150 to 350 feet deep.

The accompanying map of the artesian basin and the old course of the Rio Grande River was made by the departmental agent during his examination of this valley last May. The exterior boundaries of the artesian basin vary but the slightest degree, at one or two points, from the line laid down by Prof. Louis G. Carpenter in a map accompanying one of his latest reports. The professor's map, however, presents none of the lines of the subsidiary basins and is not as full in other respects. The artesian area of the San Luis Valley is divided into five distinct minor basins as set forth on the map, which is so full as to need no further illumination. The north line of basin No. 2 is the valley divide; lateral No. 2 of the San Luis Canal is along this ridge. Just across the river in basin No. 3; the stratum seems to make a huge dip, and it is with the greatest difficulty that a well can be maintained on account of the quicksand. Artesian wells are little used for irrigation at present, because only a part of the land capable of irrigation by the water in sight from the various sources of surface supply has been cultivated. The Alamosa "town well," as reported by City Surveyor and Engineer Jones, is the principal source of supply for the 30 miles of irrigating ditches within the corporate limits of Alamosa. One of the factors to be considered in the study of the San Luis artesian basins is the vast underflow of the Rio Grande. During the low stages of the water the six large canals taking water from that river between Del Norte and Alamosa throw solid sack dams across the river at their headgates. At each dam every drop of surface water in the river is stopped and diverted into the ditch, leaving the river bed dry just beyond the dam. Within a quarter of a mile, however, the river begins to fill again from the bottom and sides, and although in the short stretch of river mentioned it is dammed six times, at Alamosa there is more water in the river at the lowest stage than was the case before the canals were taken out and the water diverted.

The soil and the climate of the San Luis are eminently fitted for the cultivation of all the root crops, and the hardy fruits and berries prosper. In the upper part of Saguache County, at the northern part of the valley, some fine apples were gathered by Mrs. A. L. Lyons from two year-old trees; and from a plot of ground 50 by 70 feet, planted to red currants, Mr. Bonner sold 488 quarts of fruit worth $71.40, or at the rate of $900 per acre. Crab trees will bear the first year after planting, and yield good crops the second; natural grasses cover nearly the entire valley, and comprise gramma, bunch, buffalo, wild redtop, blue joint, wire grass, wild millet, and dozens of other varieties. The land, with irrigation, produces oats, 60 to 80 bushels per acre; wheat, 35 to 50 bushels per acre; barley, 40 to 60 bushels per acre; peas, 30 to 50 bushels per acre; potatoes, 100 to 400 bushels per acre. All hardy vegetables do well; hay from 1 to 3 tons per acre; hops are a natural product and yield abundantly. Prices of grain at nearest markets range from $1 to $2 per hundredweight; potatoes, from 75 cents to $1.25; hay, from $10 to $15 per ton, baled. Michael White, assessor of Saguache County, gives the following as his experience of farming by irrigation in the San Luis Valley:

Wheat	bushels per acre	30
Oats	do	35
Barley	do	40
Pease	do	40
Potatoes	do	175
Grasses:		
Alfalfa (two cuttings)	tons per acre	4½
Native grass	do	1½

The yields for some of the crops, it will be noted, are very high for averages, but under reasonably good farming experienced men may greatly increase these figures.

Under the four canals mentioned, 69,000 acres of land are cultivated by the ditch companies, and 41,760 acres by the owners of water rights, making a total of 110,760 acres.

Small canals from the Rio Grande River, Sagauche, Trenchara, Alamosa, and San Luis creeks, and other small streams, afford water for about 165,000 acres more, all under close cultivation and in the hands of small farmers. There are about 610,000 acres under ditch in the San Luis Valley, and 1,100 miles of main canal.

It may be said, however, that the possible area of cultivation is equal to the arable extent of the basin. The level valley floor seldom needs further preparation for farming than grubbing out the natural growth, which may be generally done by deep plowing. The land is worn as even as the bed of a long-used reservoir from which the water has been allowed to drain. No serious trouble is experienced from alkali, and when adequate population seek homes on its fertile acres, it is well within the bounds to say that the soil alone will support a large population. The great trouble in farming heretofore in this region is that the stockmen, desirous of reserving winter forage for their herds, have systematically opposed agricultural settlement. The problem of control of the valley has, however, been solved, and the rapid construction of railroads assures the steady growth and prosperous life of the communities within this region.

Irrigation by Seepage, San Luis Valley, Colorado.

ANSWERS FROM CORRESPONDENTS.

The following summaries are made from replies received to circulars sent by this office:

ARAPAHOE COUNTY.

J. A. Clough, Denver (October, 1891):

Total area in State under canals, about 5,000,000 acres.

Under cultivation under the smaller and older canals, 75 per cent; under the newer and larger canals, 25 per cent.

Average cost per acre of irrigation works, canals, etc: For the larger canals, from $6.25 to $8; for the smaller canals, from $8 to $12.

Cost per acre for annual maintenance and repairs for smaller canals, about 40 cents; for larger canals, from 15 to 25 cents.

Average cost per acre for preparing land for cultivation by irrigation: Breaking, $2; removing sagebrush, 50 cents; farm laterals, 25 cents.

Staple products under irrigation: Wheat, oats, barley, millet, potatoes (and in the smaller valleys), corn—in the order of their acreage; also clover, timothy, and alfalfa hay, and peaches, apples, pears, plums, apricots, and all small fruits yield abundantly.

Yield per acre: Wheat, 25 bushels; oats, 45 bushels; barley, 35 bushels; potatoes, 150 bushels; pears, 25 bushels; corn, 30 bushels; clover and timothy, 2½ tons; alfalfa, 5 tons.

Denver (post-office), W. E. Alexander (secretary, etc., Denver Land and Water Storage Company), October, 1891:

Water supply, Cherry Creek. (Running stream with spring and fall floods.)

Area under ditch, 40,000 to 50,000 acres.

Area under cultivation, 3,000 acres, now being plowed and prepared for cultivation under irrigation.

Irrigation works, 32 miles main canal; 18 feet wide on bottom; 3 feet through cut; 40 miles main laterals; 4 feet wide at bottom. Masonry dam, 68 feet high, 635 feet long, 83 feet wide at center. One subreservoir, earthen embankment; area, 69½ acres; 30 feet deep. (Three others projected.)

Cost: Main reservoir, subreservoirs, and canals have cost $439,000 to date, and $75,000 to $100,000 more will be expended.

Average cost per acre for preparing land for cultivation under irrigation, from $2 to $5.

Average cost per acre of irrigation works, ditches, etc., from $5 to $15.

Average cost per acre for annual maintenance and repair, 50 cents to $1.50.

Annual rental cost for water, $2 per acre.

Products: Potatoes, alfalfa, and all garden truck. Soil *especially* adapted to growth of apples, pears, plums, prunes, grapes, and berries, etc.

Estimated value of products per acre, from $250 to $600.

Denver (post-office), C. J. Combs (October, 1891):

Has 15½ acres under ditch and cultivation; takes his water supply from "Rocky Mountain ditch" by means of one-quarter mile of small private ditch or lateral.

[Rocky Mountain ditch takes its supply from Clear Creek, near Golden, Jefferson County. Its length is about 15 miles. Width, top, 12 feet; bottom, 10 feet. Area under this ditch, 5,000 acres; capacity, about 5,000 inches. Rate of use of water averages 1 inch per acre, costing from $1.25 to $2 per inch. Cost of maintenance and repairs per acre per annum, about $2.50.]

Products, small fruits and orchards. (Farther from city, grain and alfalfa.)

Value of small fruits per acre, from $200 to $1,000, gross.

Denver (post-office), Thomas B. Croke (September, 1891):

Has prepared and placed under cultivation by irrigation 1,600 acres, (by building the lateral ditches and reservoirs), at a cost of $18,000, the reservoirs costing $16,000 of this sum.

Cost of water rights and laterals (when main ditch was first built) was an average of $10 per acre.

Cost of annual maintenance and repairs per acre, not to exceed 50 cents.

Area under ditch in neighborhood, 50,000 acres.

Area under cultivation in neighborhood, 12,000 acres.

Principal products: Wheat, oats, barley, corn (of short season varieties), potatoes, alfalfa, clover, timothy, and all garden products; also all kinds of fruits (except tropical).

His own crops have averaged $10 per acre net for four past years; good hay land will average about the same.

BOULDER COUNTY.

Hygiene (post-office), James Ackerman (October, 1891):

Cost of preparing 80-acre tracts of land for cultivation by irrigation (breaking, $300; lateral ditches, $25; fencing, $150), $475.
Cost per acre of irrigation works, ditches, etc., about $10.
Cost per acre for annual maintenance and repairs, about 50 cents.
Area under ditch, 90 per cent of neighborhood lands.
Staple products: All kinds of small grain and vegetables, all kinds of fruit (except peach and apricots).
Average value of product per acre: Grain, $15; fruit, $100.

Langford (post-office), C. E. Barber (Setember, 1891):

Cost per acre of preparing land for cultivation by irrigation, $5.
Cost per acre of irrigation works, ditches, etc.: For a 10-mile ditch carrying 5,000 inches of water, covering 4,000 acres, $40,000 or $10 per acre (average of four ditches in neighborhood).
Cost per acre of annual maintenance and repairs, 10 cents (on a 10-mile ditch). Chief products (by irrigation) and yield per acre: Wheat, 20 bushels; oats, 40 bushels; corn, 30 bushels; alfalfa, 8 tons.

Grazing land is not irrigated.

CHAFFEE COUNTY.

Riverside (post-office), George Leonhardy (September, 1891):

Has 550 "acres under ditch;" 160 acres under cultivation.
Water supply, Arkansas River, has two ditches (supplying 400 miner's inches). Combined length, 5 miles; width at bottom, 4 and 6 feet; top, 6 and 8 feet; head gates, 2.
Cost per mile of ditches, etc., $2,500.
Cost per acre of ditches, etc., $15.
Cost of water to user per acre, $10.
Annual rental per acre, $2.
Cost of annual maintenance and repairs per acre, 50 cents.
Cost of preparing land for irrigation (fencing and clearing), $2 to $15.
Area under ditch in neighborhood, 1,500 acres.
Area under cultivation in neighborhood, 500 acres.
Chief products (under irrigation): Wheat, oats, barley, rye, potatoes, peas, turnips.
Value of annual crops, $20 per acre.

CONEJOS, COSTILLA, RIO GRANDE, AND SAGUACHE COUNTIES.

R. C. Nisbet (Dawkins, Pueblo County, December 10, 1891) writes of the San Luis Valley as follows:

Main water supply, Rio Grande River, its tributaries and artesian wells.
Area under ditch, 2,000,000 acres.
Area under cultivation, 100,000 acres.

"The Rio Grande system covers the above-named four counties, an area of about 60 miles square. There are twenty-six streams flowing into San Luis Valley and but one flowing out, hence the large artesian supply."

Irrigation works, about 4,000 miles of ditches; seven large canals; largest 60 feet wide on bottom; other six are 40 feet wide on bottom; about five hundred ditches, large and small, with separate head gates. There are "hundreds" of artesian wells; no reservoirs.
Cost of ditches and wells: Ditches, from 10 cents to 12 cents per yard, land level. Artesian wells cost from 25 cents to 60 cents per foot, including pipe (not over 2 inches).
Cost per acre of ditches, "taking all the land covered by the ditches, $1.50 to $2 per acre would construct them."
Average cost per acre for preparing land for cultivation through irrigation: About one-half the land is prairie, requiring merely plowing; other half sagebrush, greasewood, or chico, costing for clearing, etc., from $1 to $1.50.
Average cost per acre for maintenance and repairs, from 20 to 30 cents.

Cost of water supply to user, $500 for 80-acre tract (perpetual water right).
Annual rental cost, $1 per acre.
Staple products and average annual yield per acre: Wheat, 25 to 30 bushels; oats and barley, 40 to 50 bushels; potatoes, 175 to 200 bushels.

CONEJOS COUNTY.

Alameda (post-office), L. W. Smith (October 3, 1891):

Whole township (except three ranches having artesian supply) served by Empire Canal, with supply from Rio Grande del Norte River; 30 miles canals or ditches; width at top 60 feet, botttom 40 feet; two head gates.
Cost of irrigation per acre, with supply from river by canals or ditches, $8.00.
Cost of irrigation per acre, with supply from artesian sources (with reservoirs, etc.) $7.50.
Cost of annual maintenance and repairs, per acre 20 cents.
Chief products (by irrigation) and yield per acre: Wheat (30 bushels), oats (50 bushels), barley (40 bushels), potatoes (250 bushels), alfalfa, and vegetables.

[Mr. Smith has 160 acres under cultivation by means of artesian irrigation; states that artesian supply is easily obtained, etc.; cheapest and most permanent; that canal and ditch supply is good for only four months in the year. Two other large ranches have artesian wells, but no data of same is given.]

COSTILLA COUNTY.

San Luis (post-office), E. C. Van Diest (October, 1891):

Water supply, Rio Grande River, Sangre de Cristo, Ute, Trinchora, Culebra, and Castilla Creeks.
Area under ditch, 100,000 acres; area under cultivation, 65,000 acres.
Irrigation works (mileage and size of canals and ditches not given): One reservoir (not completed), storage capacity over 127 acres (27 to 30 million cubic feet); dam 1,300 feet long; height, 18 feet.
Cost per acre: Large canals, $1.00 to $1.60; smaller farm ditches, 75 cents to $1.00.
Cost per acre for preparing land for cultivation by irrigation: Grubbing (sage brush) $1.30; plowing, $2.15; subsidiary ditches, $1.00—$4.45; fencing (wire), $1.60.
Cost per acre for maintenance and repairs, per annum: Large canals and ditches, 70 cents to $1.00; small canal and ditches, 25 cents to $1.00.
Products and yield per acre: Oats (25 bushels), wheat (22 bushels), barley (24 bushels), hay (1 ton), peas, Mexican beans, potatoes, alfalfa (limited), upland hay.

EL PASO COUNTY.

Colorado City (post-office), A. Z. Sheldon (September, 1891):

Water supply, Fontaine qui, Bouille River, and tributaries, South Platte, Four-Mile Creek, Big Sandy Creek, Horse Creek, Rule Creek, West Creek, Trout Creek, etc.
Works, 220 miles main ditches; varying from 12 to 18 feet wide at top and 2 to 4 feet on bottom; seventy-five reservoirs, with areas of from 1 acre to 80 acres; head gates, about fifty (about fifty main ditches, each supposed to have a head gate).
Cost of reservoirs, from $300 to $25,000.
Cost of ditches per mile, from $300 to $1,000 (approximately).
Cost of ditches, etc., per acre, about $5 (approximately).
Cost of preparing land for cultivation by irrigation (plowing), $2.50 per acre.
Cost for annual maintenance and repairs per acre, about 30 cents.
Area under ditch, 20,000 acres.
Area under cultivation, 12,000 acres.
Staple products and annual yield per acre: Wheat, 25 bushels; oats, 40 bushels; corn, 50 bushels; barley, rye, potatoes, 200 bushels; hay, 1½ tons; cabbage and other vegetables, fruits of temperate zone, and grasses.

FREMONT COUNTY.

Cañon City (post-office), Ute Park improvement Company (September, 1891), land probably near Beaver Creek (post-office):

Area under ditch, 3,500 acres; water supply, Beaver Creek.
Irrigation works, 7 miles main canal; width, 8 feet top, 6 feet bottom; 2 feet deep; grade of 2 inches to 100 feet; capacity, 60 cubic feet per second; 10 miles laterals; reservoir covers 117 acres; dam, 40 feet at greatest height; one head gate (under construction).

Cost of main canal per mile, about $1,000.
Cost of reservoirs, about $10,000.
Cost of water supply to user, per acre, $10; permanent right.
Value of land without water supply, not worth occupying.
Value of land with water supply, $100 per acre.
Products under irrigation: Apples, pears, peaches, apricots, alfalfa, potatoes and all fruits and vegetables of the temperate zone. (Land, etc., fitted for the growth of wheat, oats, barley, rye, etc., but fruits, etc., considered most valuable crops.) Alfalfa is cut three to four times a year, and yields as high as 5 to 7 tons per acre per annum; worth $6 per ton.

An artesian well struck in vicinity, flowing 3 cubic feet per second.

Cañon City (post-office), Thomas S. Wells (October, 1891):

System includes 5 miles of ordinary canals on each side of Arkansas River (10 miles); each canal 12 feet wide; two head gates; area under ditch about 4,000 acres; area under cultivation, 2,500 acres.
Cost per mile of works about $1,200.
Cost per acre of works, $3 for main, $1 for laterals.
Cost per acre for maintenance and repairs, 80 cents to $1.
Cost per acre for preparing land for cultivation by irrigation, same as breaking ordinary prairie, merely plowing.
Cost per acre of water to user: Ditch owned by land owners.
Staple products under system: Fruit, garden stuff, and alfalfa.
Value of products: Fruit and garden yields $150 per acre; alfalfa produces about 5 tons per acre; value, $45 per acre.

GARFIELD AND PITKIN COUNTIES.

J. C. Kennedy, C. E. (secretary and general manager Thompson Irrigation Land and Water Supply Company, of Steamboat Springs, Routt County):

Water supply, north and middle forks Thompson Creek; supply, perennial; capacity, 80 cubic feet per second.
Works, two ditches, 17 and 18 miles in length; the 17-mile ditch uses for 7 miles the natural channel of a small stream, Edgerton Creek; width 12 feet at top, 8 feet at bottom, 2 feet deep, increasing in size as new streams are tapped; 10 or more reservoirs; 47 head gates on both ditches (size of dams, etc., not given).
Area under ditch, 11,000 acres; under cultivation, 200 acres.
Cost per mile of ditches about $600; cost of water supply per acre, $4 (estimated).
Cost of preparation of land for cultivation by irrigation, $6 per acre.
Average cost per acre of irrigation works, $4.
Products: Wheat, oats, rye, barley, potatoes, and other vegetables, alfalfa, etc.

KIOWA COUNTY.

Arlington (post-office), J. W. Parker, secretary, Sand Arroyo and Triple Lake Canal Company (September, 1891).

Area under ditch by this system, 1,300 acres.
Water supply, Sand Arroyo Creek; irrigation works (in progress), 4 miles main canal; 7 miles laterals; three reservoirs (areas 40 acres, 69 acres, and 71 acres); main canal, 10 feet wide, 2 to 5 feet deep; outlets of reservoirs, 12 feet wide (top), 4 feet (bottom), 7 feet deep.
Cost of canals (or ditches) per mile, $75 to $150.
Cost of preparing land for cultivation by irrigation, $3.50 per acre.
Cost of water per year, $1 per acre.
Cost of water, perpetual water right, $7 per acre.
Cost of annual maintenance and repairs, 25 cents per acre.
Products and annual yield of same: Wheat, 15 bushels; oats, 35 bushels; corn, 25 bushels; rye, 25 bushels; sorghum, 5 tons; potatoes, sweet, 50 bushels; Irish, 75 bushels; vines of all kinds grow well.

It is proposed to cultivate 200 acres next season, irrigated by this system.

LAS ANIMAS COUNTY.

Downing (post-office), S. W. De Busk; Trinidad (post-office), F. D. Wright (data for county generally):

Principal water supply: Las Animas or Purgatoire River.
Area under ditch, 51,562 acres; under cultivation, 30,020 acres. At least 50,000 acres more could be served by aid of storage works.

Irrigation works: 95 main ditches, about 300 miles total length; 10 larger ditches are from 8 to 15 miles long, 14 feet wide at top, 10 feet at bottom, 2½ feet deep; other ditches from 2 to 4 miles long, 5 to 6 feet wide at bottom, 2 feet deep; 2 reservoirs, area of one, 80 acres, area of other unknown; head gates, 95 (one to each main ditch).
Cost of ditches per mile, from $10 to $100.
Average cost per acre for irrigation works: Ditches, etc., $1 to $10.
Average cost per acre for preparing land for cultivation under irrigation, from $2.50 to $10 (mere plowing of prairie land cost $2.50 per acre; clearing land having growth of wild plum, locust, or cottonwood has cost $10 per acre).
Average cost per acre for annual maintenance and repairs, about $1.
Products and yield per acre: Alfalfa, 4 or 5 tons; blue stem, 1 ton; oats, 40 to 80 bushels; oats are generally cut and cured as hay; corn, 25 to 40 bushels; wheat, 30 bushels; barley, rye, sorghum, vegetables do well; beans average 40 bushels; apples, grapes, and garden truck.

LA PLATA COUNTY.

Durango (post-office), J. B. Harper (November, 1891):
Water supply, Florida River; area under ditch, 6,500 acres; under cultivation, 1,800 acres.
Irrigation works, open ditch on contour line; length of main ditch, 10 miles; width, top, 10½ feet; bottom, 6 feet; 3 feet deep; one headgate; no reservoirs; 250 feet flume; 8 feet wide; 4 feet deep.
Cost per mile of works, $1,900 (for main ditch).
Cost of water supply to user per acre, $10.
Cost of preparing land for cultivation through irrigation, per acre: Sagebrush land, $7; oak land, $50; pine and cedar, $20.
Average cost per acre of irrigation works, ditches, etc., about $10, as first cost. (This depends upon the amount of land furnished from one ditch.)
Cost per acre of annual maintenance and repairs, 75 cents.
Products: Wheat, oats, and alfalfa.
Estimated annual product per acre: Wheat, 20 bushels; oats, 45 bushels; alfalfa, 3½ tons (but yield increases with age).

LARIMER COUNTY.

Berthoud (post-office), S. W. Cole (September, 1891):
"Home supply ditch;" water supply, Big Thompson Creek (which rises at the foot of Long's Peak; fed by snows of mountain and foothills; the supply is ample at the first of the season and thousands of inches are wasted; later, water is much needed).
Area under ditch, 20,000 acres; under cultivation, 18,000 acres.
Irrigation works: Ditch, 20 miles long; width, 20 feet at top, 16 feet at bottom, for 15 miles, thence smaller; one stone dam at head of ditch 60 feet long, 50 feet high; one large earth dam, one-half mile long; one earth dam, one-quarter mile long; two reservoirs, each covering 400 acres; three large bulkheads; 115 small headgates. (Many farmers have private reservoirs with areas from 10 to 30 acres, 10 to 20 feet deep.) One long wooden flume about 2,000 feet.
Cost of works: Main ditch per mile, $4,000; 2 reservoirs ($20,000 each), $40,000; total cost (20-mile ditch, $80,000; reservoirs, $40,000), $120,000.
Cost of water supply to user per acre, $4; cost for maintenance and repairs per acre, 10 cents.
Average cost per acre for preparing land for irrigation: Plowing or breaking, $3; fencing (3 wire close posts), $1; surveying and making ditches inside of fence, 15 cents.
Cost of 2 miles of main lateral ditch per acre, 90 cents.
Products under irrigation: Wheat (mostly), next oats, barley, corn, potatoes, alfalfa (many acres). (For few last years nearly every farmer has started an orchard.)
Estimated values of product per acre, $14; forage, $12.

Fort Collins (post-office), A. N. Hoag (September, 1891):
"Dry Creek Ditch," water supply, Cache la Poudre River.
[An old ditch established by farmers who claim what water they need, or 50.92 cubic feet per second; average amount for three hundred days in 1891 was 25 cubic feet per second. There are twenty-four shares in ditch, worth $1,000 per share.]
Works: 12 miles main ditch; width at bottom, 12 feet at upper and 7 feet at lower end; one dam; two headgates; one weir.
Cost per mile, main ditch, $2,000.

Average cost per acre of works, about $20; average cost per acre for preparing land for cultivation (under irrigation): Breaking, $3; laterals, $1.50; fencing, $2; total, $6.50.

Average cost per acre for maintenance and repairing per annum, $1 (including laterals).

Cost of water supply per share, $1,000; annual cost for repairs, per share, $25.

Area under ditch, 2,600 acres; under cultivation, 2,300 acres.

Staple products under irrigation: Cereals, alfalfa, native hay, vegetables of all kinds, and fruit.

Value of product per acre: From $20 to $300 (fruit); alfalfa from $20 to $40.

LARIMER AND WELD COUNTIES.

Hon. B. H. Eaton, Greeley, Weld County, Larimer and Weld Canal:

Water supply, Cache la Poudre River (mountain stream); area under ditch, 40,000 acres; under cultivation, 34,000 acres; irrigation works, 52 miles; canal, 28 feet wide on bottom, 6 feet deep, with slope of 1¼ to 1 foot: two large reservoirs (being constructed) with aggregate depth of 23 feet over 650 acres; many smaller (private) reservoirs; one main headgate; 90 lateral headgates.

Cost of canal per mile, $3,000.

Cost of reservoirs (two being constructed by the 500 water-right holders), $75,000 to $100,000.

Cost of water supply to user per acre (perpetual water right), $15.

Cost per annum for maintenance and repairs, $10 for 80-acre tract, or 12½ cents per acre.

Cost for preparation of land for cultivation (plowing), $2 per acre.

Staple products: Wheat (averaging 30 bushels per acre), oats, barley, alfalfa, potatoes, cabbages, onions, etc.

MESA COUNTY.

Grand Junction (post-office), C. W. Steele (October, 1891):

Water supply, Grand and Gunnison rivers and small streams.

Area under ditch, 48,000: Grand Valley, 40,000; elsewhere in county, 8,000 acres.

Area under cultivation, 15,000 acres.

Works: Grand River system, two large canals or ditches, one headgate; Gunnison River, water wheels, other works, three pumping plants, to serve 2,400 acres; ditches from smaller streams.

Mileage and size of canals: 75 miles; largest, 50 feet wide on top, 38 feet on bottom; next largest, 24 feet on bottom.

Cost per mile, main canals, $7,500.

Cost of water supply to user per acre, $10.

Annual rental cost $2.80 per inch. (Owners of water rights or royalty pay assessments of from 12½ cents to 87½ cents per acre per annum.) Average cost per acre of annual maintenance and repairs, 20 cents.

Average cost per acre of irrigation works, ditches, etc., $10 (from Grand and Gunnison rivers; less from smaller streams).

Staple products under irrigation: Wheat, oats, corn, alfalfa, fruits, potatoes, and other vegetables in variety.

Grand Junction (post-office), J. Clayton Nichols and Messrs. Crawford & Miller (October, 1891):

Grand River Canal or ditch: Water supply, Grand River (abundant supply).

Area "under ditch," from 34,000 to 45,000 acres; under cultivation, from 15,000 to 18,000 acres.

Irrigation works: Canal, 52 miles; 38 miles main canal; width, 50 feet on top, 30 feet on bottom (40 feet at headgate); one headgate; no reservoirs or other works.

Cost per mile of canal, about $6,000.

Cost of water supply to user, per acre, from $10 to $16; annual rental cost, $1 to $1.75.

Average cost per acre for preparing land for cultivation under irrigation, $2.50 to $3.

Average cost per acre for annual maintenance and repairs, 12½ cents to 62½ cents.

Average cost of irrigation works, from $5 to $16.

Staple products under irrigation: All kinds of semitropical fruits (especially peaches, pears, apples, apricots, nectarines, grapes, and almonds); also oats, wheat, corn, potatoes, and alfalfa.

Estimated value of product per acre, $15 to $25 (for oats, etc., and alfalfa); $300 to $500 for fruits.

"This valley is celebrated for its apples, peaches, pears, grapes, apricots, almonds, nectarines," etc.

Grand Junction (post-office), D. C. Hawthorne (October, 1891):

"Crawford Ranch;" has a private ditch; water supply, Rapid Creek (a mountain stream heading in the Great Mesa Mountain).
Works: Ditch, 1¼ miles in length; width at top, 4 feet; at bottom, 2½ feet; one stone dam; one headgate (cheap).
Area under ditch, 100 acres; under cultivation, 60 acres (orchard and vineyard).
Cost of ditch (1¼ miles), $1,000; cost of annual maintenance and repairs, about $60.
Products: Nothing grown but fruits (except for family use); orchard set out spring of 1890.

Grand Junction (post-office), Mrs. Kate Harlow (October, 1891):

Has private ditch; water supply, Rapid Creek (which heads in Grand Mesa Mountain and empties into Grand River on her place); creek has a fall of 5,000 feet in the 6 miles of its length.
Nature of works: Ditch about one-half mile long, 3 feet wide; one headgate; also simple stone dam; no other works.
Cost of ditch, about $1,800; area under ditch, 80 acres; under cultivation, 35 acres.
Cost of maintenance and repairs per year, about $200.
Products: "Nothing but fruit and vegetables; country is new."

Grand Junction (post-office), Messrs. Miller & Wallace (October 19, 1891):

Have private ditch; water supply, Wallace Creek (which heads in Battlement Mesa Mountain); average flow, 4 cubic feet per second.
Area under ditch, 640 acres; under cultivation, 320 acres.
Works, ¾ mile of ditch, 18 inches on bottom, 3 feet on top, 18 inches deep, grade ¼ inch per rod; one headgate 3 feet wide (no reservoir).
Cost of entire ditch, $750 (about).
Average cost per acre of ditches, etc., $5.
Cost of water supply to user per acre, $2.25.
Average cost per acre for preparing land for cultivation under irrigation, $8 (sagebrush land under this ditch). Average cost for land in Grand Valley around Grand Junction, about $2.50.
Cost per acre for annual maintenance and repairs, from 10 cents to 25 cents.
Products under irrigation: Alfalfa, wheat, oats, barley, potatoes.
Estimated value of annual product, $15 per acre; irrigated grazing land, $1.50 per acre. Altitude of Wallace Creek, 6,000 feet.

Whitewater (post-office), John Goldsby (October, 1891):

Has private ditch covering 75 acres; water supply, East Creek (which empties into Gunnison River); ditch 1 mile in length, 6 feet wide at top, 2½ feet at bottom, claims 100 inches water; one reservoir dam 200 feet long, 7 feet high.
Cost of ditch, $350; cost of reservoir (dam, etc.), $450; annual repairs, etc., per annum, $1.
Cost per acre for preparing land for cultivation under irrigation $40 (land, so-called "bottom land," covered with heavy growth of willow, etc., requiring labor and money to "grub" out).
Staple products: Fruits of various kinds, alfalfa, wheat, oats, corn, and other small grains.
Annual product per acre: wheat, 30 bushels; corn, 40 bushels; oats, 75 bushels.

MONTROSE COUNTY.

Montrose (post-office); Judge John C. Bell (October, 1891); general data (estimated) for Montrose County.
Principal source of water supply, Uncompahgre River; area under ditch, 200,000 acres.
Irrigation works, about 200 miles of large and small canals and ditches; no reservoirs; head gates numerous, costing from a small amount up to $5,000.
Cost of canals, ditches, etc., per mile, widely varying; probably from $100 to $2,000.
Preparing land for cultivation by irrigation. [Most of the county is mesa land, with no wild growth but white sage, easily plowed up; some exceptional cases, where cost would be $50 per acre to prepare.]
Cost of water to user per acre, $3.25; annual rental cost, $1.25.
Cost of annual maintenance and repairs on minor ditches, merely nominal; on large canals, considerable, but varying greatly; no estimate.
Products: Wheat, oats, barley, rye, alfalfa, clover, timothy, and all kinds of vegetables and fruits. (Is a great fruit and alfalfa county, and with present prices fruit pays better than anything; alfalfa next in value.)

Yield of wheat per acre, 25 bushels, worth 80 cents per 100 pounds; oats, 60 bushels, worth $1.25 per 100 pounds.

OTERO COUNTY.

Rocky Ford (post-office); Messrs. C. G. Ament & Co. (September, 1891):

Water supply, Arkansas River. Irrigation works. Canal 80 miles in length; width, 20 feet wide on bottom, 24 feet wide at top (at the head), 8 feet wide at lower end of canal; one head gate; no reservoirs.
Area under ditch, 35,000 acres.
Area under cultivation, 5,000 acres.
Cost per mile of canal, $1,500.
Cost per acre for annual maintenance and repairs, 10 cents to 25 cents (on actual amount of water purchased).
Cost of irrigation works per acre for 160-acre tracts (all under cultivation). Water right, $1,200; laterals and head-gate, $100. (Farmers do not generally buy enough water to cover their whole farms.)
Cost per acre for preparing land for cultivation by irrigation: Breaking wild land, $1.75 per acre; for grazing, 25 cents per acre for laterals.
Cost of water supply to user, $10 per acre (perpetual water right).
Products and yield (of same) per acre: Wheat (25 bushels), oats (35 bushels), corn (30 bushels), beans (20 bushels) alfalfa, hay), 6 tons; seed (5 bushels), sweet potatoes, melons, and all "truck" raised extensively.

Catlin (post-office); Robert McLain (October 25, 1891):

Water supply, Arkansas River; area under ditch, 15,000 acres.
Area under cultivation, 13,000 acres.
Irrigation works:
Large canal, length 35 miles; width, top, 30 to 38 feet; bottom, 20 feet.
One dam across river (308 feet long, 16 feet wide), of lumber and piles.
One head gate; no reservoirs.
Cost per mile of works, about $1,800.
Cost of water supply per acre, $10. (Perpetual water right.)
Cost of preparation of land for cultivation (per acre), by irrigation, $2.50.
Cost of preparation of land for grazing (per acre) by irrigation, $1 (grass).
Cost of maintenance and repairs per annum, per acre, about 15 cents.
Annual rental cost of water, $1.50 per acre (when sold by the year).
Staple products (and yield per acre) under irrigation: Wheat (25 to 40 bushels), oats (30 to 60 bushels), corn (25 to 40 bushels), hay (3 tons), alfalfa, beans, sweet potatoes, and other vegetables.

La Junta (post-office); C. R. McBride (October 5, 1891):

Arkansas Valley Canal, supply, Arkansas River (north side).
Length of canal, 120 miles; width, 60 feet at top; 30 feet bottom (at headgate); 2 reservoirs.
Head gates, 100; area under ditch, 165,000 acres: under cultivation, 32,000 acres.
Cost per mile: Ditches, $3,000; cost of reservoirs, etc, $5,000.
Average cost per acre of irrigation works, $5.50.
Average cost per acre for preparing land for cultivation by irrigation, $6.
Average cost per acre for maintenance and repairs per annum, 15 cents.
Cost of water supply to users per acre, $12.50.
Annual rental cost per acre, $1.50.
Products under irrigation and yield of same per acre: Alfalfa (4 tons), wheat (25 bushels), corn (30 bushels), oats (50 bushes), barley (30 bushels). Vegetables and fruits grow to perfection.

La Junta (post-office); J. H. Nelson (October, 1891), chief engineer Colorado Irrigation Canal Company:

Irrigation Works, Otero Canal; Water supply, Arkansas River (south sine; canal 105 miles long; width top, 32 feet; bottom, 20 feet; five flumes; two headgates; one waste gate; no reservoirs.
Average cost per mile of works, $3,000; average cost per acre, $5.50.
Average cost per acre for preparing land for cultivation: Plowing, $1.75; laterals, 5 cents ($2.25); fencing, $1.
Average cost per acre for maintenance and repairs, 15 cents.
Average cost of water to user per acre, $10 (water right).
Area under ditch, 74,000 acres; under cultivation, 18,000 acres.
Products (under irrigation) and yield per acre per annum: Alfalfa (4 to 5 tons), wheat (24 bushels), oats (4 to 5 bushels), corn (30 bushels), rye (20 bushels) clover (3 tons), timothy (2 tons), berries, grapes, and other fruits and vegetable.

PROWERS COUNTY.

Lamar (post-office); Santa Fe Land and Canal Company (November 21, 1891):

Source of supply, the Arkansas River. Canal being constructed to be 65 miles long; width on top, 26 feet; on bottom, 16 feet; depth, 5 feet; number of head gates, 3; cost per mile (average) $500; cost of works per acre, $7.50; cost of water supply to user per acre, $10 (water rights).
Cost of maintenance and repairs per annum per acre, 15 cents.
Cost of preparing land for irrigation, $2.40; plowing, $2; harrowing, 40 cents, per acre.
Area under ditch, 30,000.
Staple products (under irrigation): Alfalfa, wheat, oats, millet, vegetables and melons.
Estimated annual product per acre: Alfalfa, 8 tons; wheat, 40 bushels; oats, 25 bushels.

Lamar (post-office); D. E. Cooper, secretary Bed Rock Mutual Ditch Company (October 30, 1891):

Water supply, Arkansas River.
Area under ditch, 4,500 acres.
Area under cultivation, 1,060 acres.
Length of canal, 11 miles; width at top, 12 feet; at bottom, 8 feet; 3 feet fall per mile.
Two head gates; no reservoirs.
Cost per mile of ditches, $450.
Cost of water supply to user per acre, $4.60 (perpetual right to user).
Cost of preparing land for cultivation under irrigation per acre, $3.
Cost per acre of annual maintenance and repairs, 15 cents.
Products under irrigation: Wheat, oats, barley, rye, alfalfa, potatoes, corn and fruits.
Value of annual product per acre, $18.

Circular addressed to "Secrĕtary Kansas Loan and Trust Company" was returned with data and signed as follows:

"T. B. Sweet, president Irrigation Land Company, Topeka, Kansas."

Water supply, Arkansas River (near Lamar, Prowers County, Colo.).
Irrigation works: Dam across river (no data), and 50 miles canal or ditches, 26 feet wide on top, 20 feet on bottom (being three canals brought together 2 miles east of Lamar); three head gates and some flume work (no data).
Cost of works per mile (including all works on ditches, head gates included), $2,000.
Cost of works per acre, $4 to $5.
Cost of water supply per acre to user (perpetual water right), $10.
Cost of preparation of land for cultivation by irrigation, $3.
Cost of preparation of land for grazing, native grasses, not over 50 cents.
Cost of maintenance and repairs, per acre, annually, 15 to 25 cents.
Principal products and annual product per acre: Wheat (30 bushels), oats (40 bushels), rye (30 bushels), barley (40 bushels), corn (50 bushels), alfalfa (4 to 5 tons), sweet potatoes (100 bushels), melons, etc.
Area under cultivation, 5,000 acres.
Area under ditch, 25,000 acres.

PUEBLO COUNTY.

Pueblo (post-office); R. Rosenberg, superintendent Bessemer Ditch Company (October, 1891).

Water supply, Arkansas River.
Area under ditch, 30,000 acres; area under cultivation, 7,500 acres.
Irrigation works: Mileage of ditches, 42 miles. Main canal: Width at top, 22 feet; at bottom, 6 feet; depth, 8 feet. Ten reservoirs projected. One reservoir constructed with capacity of 38,000,000 cubic feet; height of dam, 18 feet; one masonry head-gate; one siphon, 4,500 feet in length, 5 feet diameter (under St. Charles River).
Cost per mile of main ditch, $11,000; average cost per acre of laterals, $1.25.
Cost per acre for annual maintenance and repairs, 62 cents.
Cost per acre for preparing land for cultivation by irrigation, $2.50.
Staple products under irrigation—alfalfa, vegetables, grain, and maize.
Estimated annual product per acre: Alfalfa, 7 tons; grain, 30 bushels.

County statistics compiled from answers to office circulars, are from the following residents of said county: H. R. Holbrook, L. W. Smith, T. H. Brandenberg, H. T. Van Keuren, C. H. Small & Co., T. H. S. Schooley, Geo. Bell, Bardon Sweet, John Norris, C. H. Stickney, Ward Rill, Davis & McDaniel, Chas. Kretschmer, Wm. Meredith.

Estimated area in county under ditch, 300,000 acres.

Estimated area in county under cultivation, 100,000 acres.

(In immediate vicinity of Pueblo City, probably 60,000 acres under ditch.)

Water supply, Arkansas River:

Estimated average cost per acre of irrigation works in county, main ditches, etc., $10.

(Near the mountains, foothills, etc., where arroyas are found, bridges frequent, and the river banks are high, average is probably $25 per acre; on level lands, not far above river level, probably from $5 to $10 per acre.)

Average cost of water per acre, $10 (perpetual water right).

Average cost of preparing land for cultivation (by irrigation) about $3.50. (Plowing from $1.25 to $2.50; laterals, $1.25 to $1.50.)

Average cost for annual maintenance and repairs per acre, from 25 cents to $3.

Staple products under irrigation: Wheat, oats, rye, corn, barley, alfalfa, timothy, millet, blue-stem hay, potatoes, celery, sugar beets, beans, cabbage, onions and other vegetables; apples, peaches, pears, plums, grapes, melons, and all fruits of the temperate zone.

Average annual product per acre: Wheat, 20 to 30 bushels; oats, 30 to 40 bushels; corn, 40 bushels; grain generally, 20 to 40 bushels; alfalfa, 4 to 8 tons.

Average value of product per acre: Grain crops, from $20 to $30; fruit, $150; melons, $50 to $100; apples, from $100 to $200; garden truck, $250; alfalfa, $20 to $60.

Average revenue from all crops, with proper cultivation and plenty of water, from $20 to $30 per acre.

ROUTT COUNTY.

Craig (post-office), C. E. Baker (October 21, 1891).

Water supply, Snake, Bear, and Elk rivers and tributaries, ("furnishing more water than can be utilized.")

Irrigation Works, 150 miles of main canals or ditches, 6 reservoirs, covering from 3 to 25 acres.

Cost per mile of ditches, about $200.

Cost per acre for preparing land for cultivation by irrigation, average $4.

Cost per acre for annual maintenance and repairs, about 50 cents.

Cost per acre of irrigation works, ditches, etc, from $1.25 (near the mountains) to from $3 to $10 (where stream has less fall).

Products and yield per acre, under irrigation: Wheat, 30 bushels; oats, 40 bushels; potatoes, (300 bushels) and hay.

Steamboat Springs, (posto-ffice), J. C. Kennedy, C. E. (December, 1891.) Altitude, 6,700 feet.

His homestead tract has about 100 acres under two ditches taking water out of Fish Creek; 20 acres under cultivation this (the first) year; cost per acre, about $1.

"In water district No. 58 (of which he was referee this season) about 60 per cent of the water users have water rights adjudicated. Duty allowed, 1 cubic foot per second to every 60 acres. Amount of water appropriated in district 316 cubic feet per second. Total mileage of ditches, 120 miles (mostly small ones) area under ditch, about 19,000 acres, about 50 per cent of which is now irrigated."

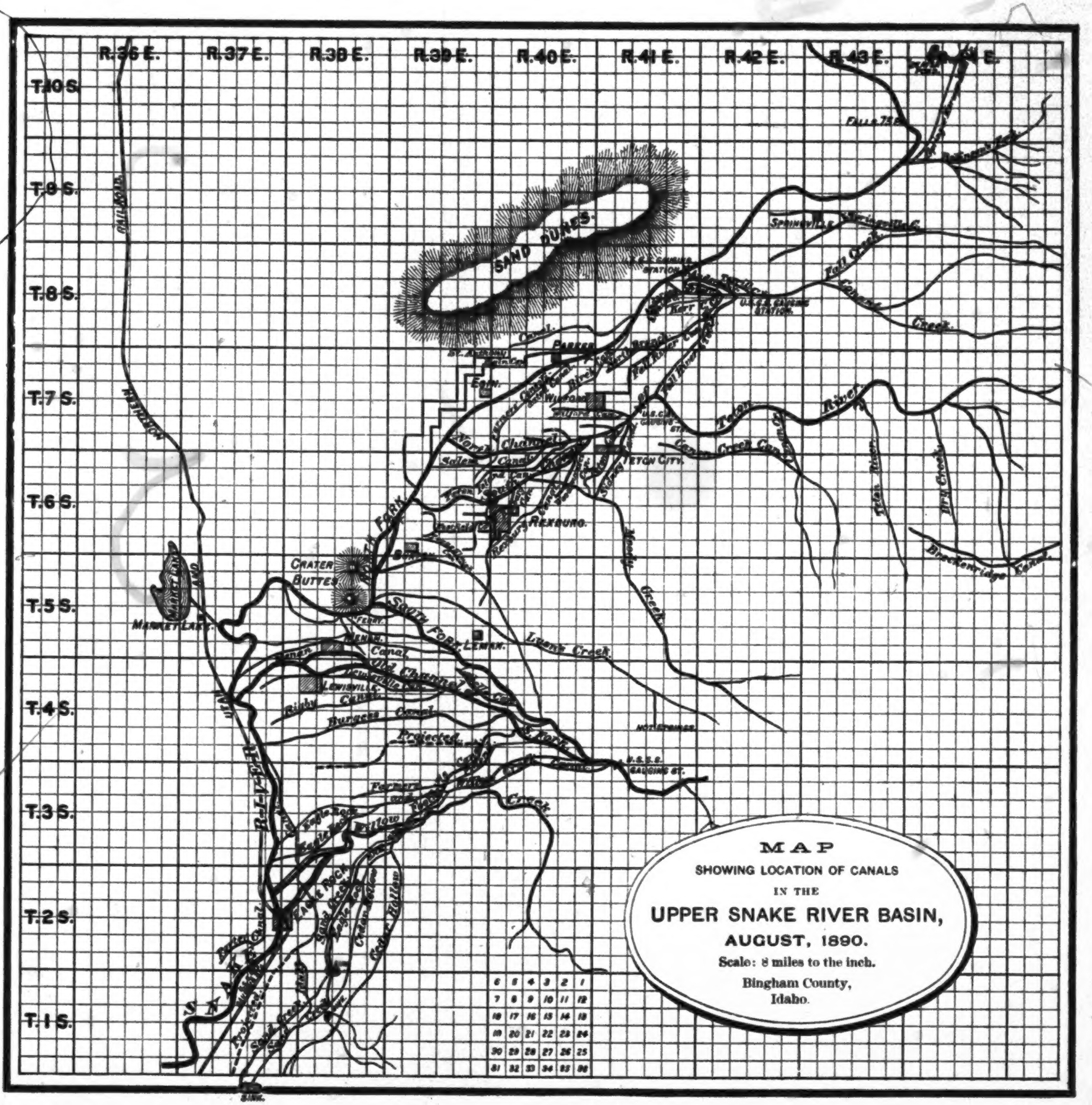
IDAHO.

Located between latitude 42° and 49° north and longitude 111° and 117.10° west of Greenwich, Idaho embraces an area of 86,294 square miles, or 55,228,160 acres. It is bounded on the north by the British Possessions and Montana, east by Montana and Wyoming, south by Utah and Wyoming, and west by Oregon and Washington. The extreme length, north and south, of its western boundary is 485 miles, while on the east along Wyoming it is but 140 miles. Its breadth is about 50 miles in the north and northeast to 300 miles in the south. The narrow portion of the Territory running between Montana on the east and southeast and Oregon and Washington on the west is known as the Panhandle. It is a region of high altitude, with large plateau and table-land areas, having numerous mountain lakes and a higher degree of humidity than any other portion of the arid region between 100° and 126° of west longitude. The remaining portions of the State consist of mountain and table lands, with an average elevation of from 2,000 to 5,000 feet above sea level. This great mountain plateau is broken by numerous depressed valleys, which form channels for some considerable streams. It is crossed also by short mountain ranges or spurs, having peaks that rise above the level, with perpetual snow. The whole area therefore is one of a great water-bearing capacity and contains many important rivers and scores of deep, placid lakes. The principal of these are: Alturas, Bear, Cliff, Cœur d'Alêne, Dry, Grays, Great Payette, Henry, Hot, Kanikau, Lincoln, Loon, North, Pend d'Oreille, Red, Fish, Swan, and Yule. The entire lake area of Idaho covers about 600,000 acres. The Pend d'Oreille is 120 miles long and from 5 to 10 miles wide. The Cœur d'Alêne is 36 miles in length and from 3 to 5 miles wide. The Kanikau is 20 miles long and 10 miles wide. These lakes and numerous others are all of them located in regions bounded by picturesque mountain ranges and having great beauty of position and scenery, which is sure in time to make them the cause of admiration by thousands of tourists.

The rivers of Idaho are all of them important and some are navigable for a considerable length. Among the most important are the Salmon, Snake, Boisé, Clearwater, Kootenai, Payette, Weiser, the Clark Fork of the Great Columbia, with the Cœur d'Alêne and St. Joseph Rivers, all of them of great size. The three latter are as large as the Ohio at Wheeling and each of them is navigable for several hundred miles. The Snake River is over 1,000 miles in length within and on the borders of the State of Idaho, and is also navigable for about 200 miles. The others named are more important in size and volume than the Susquehanna and smaller streams in the East. With these there are hundreds of tributaries, nearly all of them having swift, clear, and somewhat precipitous currents, furnishing hydraulic power to an almost illimitable capacity. The storage of water is a problem of ready solution in the State of Idaho. It will require only careful engineering and thorough construction for safety in the forming of reservoirs and in the making of channels for distribution. The Snake River is one of the most remarkable streams in character for its length, formation of channel, its volcanic features, and for the second greatest cataract and rapids upon the North American Continent, Shoshone and American Falls being among the wonders of nature in volume and picturesqueness of scenery. The basin of the Snake within the boundaries of Idaho forms an almost unbroken bed of lava and basaltic rocks for 50 miles in width and throughout its entire length. The river, as cut through by this enormous volcanic area and vast cañon, varies in depth from 100 to 1,000 feet. The streams that empty from the north into the Snake form some distance below the Shoshone and American Falls. The larger portion of this remarkable basin must remain a barren waste, so far as agriculture is concerned, though the sage brush that covers much of its surface indicates considerable fertility. The deep valleys contain a large proportion of arable land, and the foothills surrounding the basins are plenteously covered with gramma and bench grass, thus affording excellent pasturage. The extreme upper and lower portions of the Snake basin may be reclaimed for agricultural purposes by means of irrigation. The river itself will unquestionably become the great source of storage water for the reclamation of southern Idaho.

The Saw Tooth Mountains and other extensions of the Bitter Root Range appear to form a climatic division. On the east side thereof, Idaho belongs to the arid area; on the west, the climate is almost humid enough to do away with irrigation altogether. It is probable that a considerable proportion of the famous Camas Prairie of the Salmon and Clark's Fork basins will be brought under cultivation; chiefly by the aid of large surface irrigation works, which are now projected. The Bitter Root Range, with its extension, the Cœur d'Alêne, forms on the northwest a continuation of the Rocky Mountain range proper, and makes a northern termination of the continental divide within the United States. The fall of rain and snow upon this mountain divide is very considerable; but both to the east and west the valleys and table lands receive but little precipitation, and agriculture will not be found successful therein without the aid of irrigation. South of the Snake River, beginning on the east, will be found the important hydrographic basin of the Bear River and Lake. Next in importance thereto are those of the Raft River, the Salmon Fall River, and the lower portion of the Bruneau, which takes its rise in northern Nevada, numerous branches and forks of the Owyhee, which also rise in northern Nevada and belong, hydrographically speaking, as does the Bruneau, to the drainage basins of that State.

The climatology of Idaho presents remarkably favorable features for a mountain region. In the eastern and southern portions of the State the annual precipitation is about ten inches. The snow on the mountain and table lands, which comprise about four-fifths of the State, will accumulate during the winter to an average of six packed acre-feet or about four acre-feet of water. On the Saw Tooth Range and other higher mountain summits twice this average is reported or estimated to fall. Hurricanes and tornadoes are altogether unknown. The influences of the Japanese current (Kuro Shiwa) is felt to a considerable extent within a large portion of western and southern Idaho. The temperature of the winds blowing from the Northwest, which is the main current observed in Idaho, is, of course, greatly affected by the influences of this warm current. As these winds pour inward, laden with moisture and warmth, they strike the bald and precipitous high altitudes of the Bitter Root and Rocky Mountain ranges, and are thereby deflected,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SAND DUNES.
RAILROAD
MARKET LAKE
CRATER BUTTES
North Fork
South Fork
REXBURG.
TETON CITY.
PARKER
ST. ANTHONY
Egin.
U.S.G.S. GAUGING STATION.
U.S.G.S. GAUGING ST.
SPRINGVILLE
Fall Creek
Teton River
North Channel
Salem Canal
Moody Creek
Lyons Creek
Teton River
Dry Creek
Brackenridge Canal
LEWISVILLE
Menan Canal
Old Channel
Rigby Canal
Burgess Canal
Projected
Farmers
Willow Creek
Eagle Rock
Sand Creek
Cedar Hollow
Snake River
HOT SPRINGS
FALLS

MAP
SHOWING LOCATION OF CANALS
IN THE
UPPER SNAKE RIVER BASIN,
AUGUST, 1890.
Scale: 8 miles to the inch.
Bingham County,
Idaho.

depositing their moisture along the western slopes and base of the mountains, carrying their warmth if not their humidity to any great extent into the southern portion of the State. The forest area of Idaho was estimated by witnesses before the Senate Committee on Irrigation at 9,000,000 acres. Mr. Fernow, chief of the forestry division of the Department of Agriculture, estimates the area of timber land at 5,849,600 acres. Maj. Powell, in his testimony before the Senate committee, gives Idaho only 1,177,600 acres of both firewood and merchantable timber. His estimate is evidently as much too small as the estimate of the first witnesses is too large. The estimate of the chief of forestry is more correct. The lake or northern region of Idaho shows by far the heaviest timber or tree growth. The lake region lies chiefly within the counties of Idaho, Latah, Nez Perce, Shoshone, and Kootenai, and, with the exception of the western portion, none of this territory can be classified as arid. It may properly for irrigation purposes be termed sub-humid.

The agricultural lands of Idaho are estimated to embrace about 16,000,000 acres, of which at least 11,000,000 are of an arid character and require an artificial application of water by irrigation works to make them productive. In the new State thirteen of the eighteen counties are entirely within the arid belt. Probably one-tenth of the remaining five will require irrigation also. The soil may be divided into alkali; the rich warm loams of plain and plateau; that of the valleys and mountain slopes. The alkalized area is less in extent for Idaho, in proportion to its extent, than is found in any other mountain region. The greasewood and sagebrush grow abundantly thereon. The major portion of it so lies, that by means of irrigation it can be thoroughly reclaimed. The mountain and foothills soil, especially in the wooded section, is of a deep black loam of rich vegetable mold. The table, mesa, and plateau areas are covered with a soil highly mineralized, compounded of volcanic and granite detritus, and possessing all the elements necessary for the successful growth of the cereals. The valley lands contain a sandy soil, friable, warm, easily drained as well as irrigated, and showing a remarkable adaptability for the smaller grains, the temperate fruits, and all vegetable and garden products. It is of good depth, invariably superimposed on a gravelly strata, with a grade that facilitates easy working. The elevation of these valleys is usually less than 5,000 feet above sea level. Their fertility is greatly aided by the prevalence of the Chinook or Pacific winds. All of the cereals and vegetables which are raised north of the cotton belt grade can be raised in Idaho; even tobacco and cotton have been grown in the lower valleys. They are not likely, however, to prove a certain crop. For fruit growing, southern and western Idaho is becoming one of the most valuable portions of the arid region. The mountain basin or valley in which Boise is located, for example, presented before the Senate committee in August, 1889, a remarkable array of apples, plums, peaches, pears, and other fruits of the temperate zone. In size, quality, and quantity, the exhibit was of an almost astonishing character.

Irrigation has already obtained a large foothold in Idaho. In the southeastern portion thereof, embracing the counties of Bear Lake, Bingham, Cassia, and Oneida, the Mormon settlers have covered a considerable area with their minutely divided farms and their numerous and primary form of ditches. Westward of their settlements the ditch systems grow larger, though in total areas the surface of land served is not as extensive. The governor of Idaho Territory, in his last report for 1889 (made before admission into the Union), presented the following table, carefully prepared from reports prepared for the Senate Committee on Irrigation, under the direction of the governor and surveyor-general of the Territory:

	Areas (approximate).	Area in process of irrigation.	Area irrigable.	Land irrigated.	Land reclaimed.
	Sq. miles.	*Acres.*	*Acres.*	*Per cent.*	*Per cent.*
Ada	2,424	60,000	900,000	6.25	62
Alturas	2,100	14,500	268,000	5.13	21
Bear Lake	1,300	21,500	40,000	35.5	74
Bingham	12,364	284,750	2,503,500	10.5	35.5
Boise	3,024	63,500	[illegible],000	24.	18.
Cassia	5,100	82,000	655,000	11.1	22.5
Custer	4,350	24,000	446,000	5.1	16.7
Fillmore	2,700	10,000	230,000	4.2	14.
Lemhi	4,300	10,000	600,000	1.64	22.2
Logan	5,200	50,000	1,250,000	2.6	39.
Oneida	2,600	38,800	148,000	20.8	11.2
Owyhee	7,812	21,300	248,500	8.	42.
Washington	2,900	40,000	500,000	7.4	29.
	56,174	740,350	8,051,000	9.2	24.

Other testimony taken by that committee gives the total of irrigated acres at 715,500, and the mileage of ditches at 13,011. It is reasonably estimated that since then about 50,000 additional acres have been brought under ditch, of which one-fourth is now being cultivated. The total cost of the irrigation works now constructed in Idaho is not less than $2,250,000.*

In the southwestern portion of Idaho, and in the valleys of the Snake and Salmon, great ditch systems are in process of construction, the cost of which will not be less than $1,500,000. They will add an additional 250,000 to 300,000 acres to the area under water. The following reservoirs are now in use for the storage and supply of water for town purposes, obtained from springs or other phreatic waters:

County.	Town.	No.	Capacity.
Bingham	Pocatello	....	Tanks supplied by springs; 500,000 gallons.
Logan	Bellevue	1	Dam and impounding reservoir.
Alturas	Hailey	1	250,000 gallons.
Do	Ketchum	1	100,000 gallons.
Oneida	Weston Creek	1	Dam and impounding reservoir.

For irrigation purposes, the county reports made to the Senate Committee on Irrigation, including sites and estimates for storage reservoirs, made estimates as follows:

County.	No.	Estimated cost.
Bear Lake	8	$38,500
Cassia	9	550,000
Oneida	2	4,000

New irrigation works in process of construction are being carried on under the direction and capital of New York and Salt Lake City parties. The Alturas Land Irrigation Company, projected in Utah, designs to construct a dam across the Snake River to flood canals for the purpose of irrigating land on both sides thereof, in Cassia and Logan Counties. It is stated that this work will serve when completed 500,000 acres of the most valuable fruit, cereal, and vegetable land. The land to be thus served is not now worth the preëmption price of $1.25 per acre.

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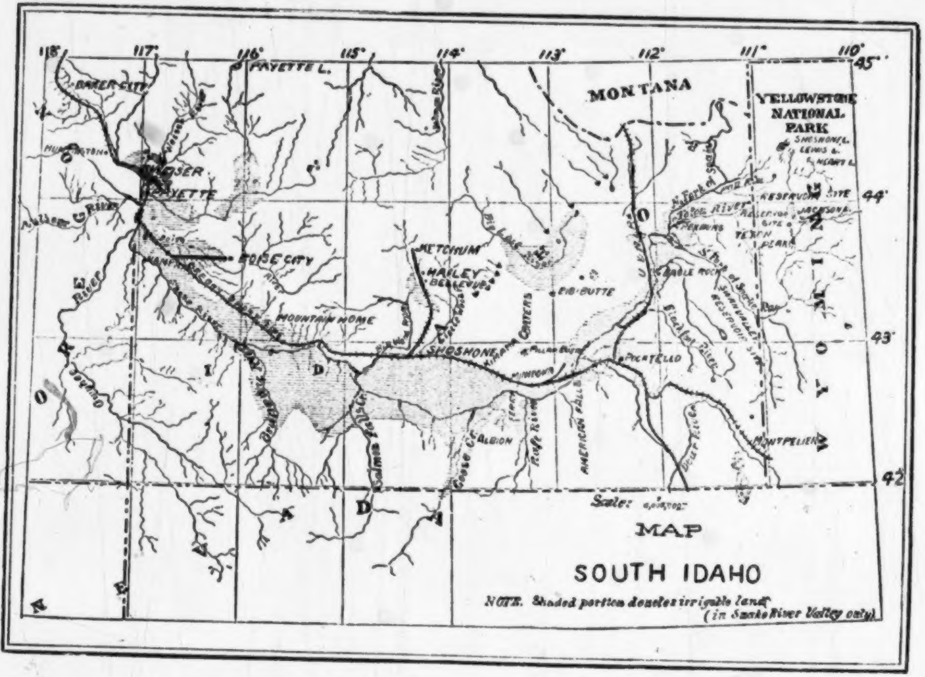
* See answers to correspondents at close of Idaho for U. S. Census figures.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MONTANA
YELLOWSTONE NATIONAL PARK
SHOSHONE L.
LEWIS L.
HEART L.
RESERVOIR SITE
JACKSON L.
RESERVOIR SITE
TETON PEAK
N. Fork of Snake R.
Teton River
EAGLE ROCK
S. Fork of Snake R.
SWAN VALLEY RESERVOIR SITE
Blackfoot River
POCATELLO
MONTPELIER
Bear River
AMERICAN FALLS
Raft River
ALBION
Goose Cr.
MINIDOKA
SHOSHONE
CRATERS
BIG BUTTE
Big Lost River
KETCHUM
HAILEY
BELLEVUE
MOUNTAIN HOME
BOISE CITY
Boise River
WEISER
PAYETTE
PAYETTE L.
BAKER CITY
HUNTINGTON
Malheur River
Owyhee River
Bruneau River
Salmon Falls Cr.
Scale:
O R E G O N
N E V A D A
I D A H O
W Y O M I N G

MAP

SOUTH IDAHO

NOTE. Shaded portion denotes irrigable land (in Snake River Valley only)

When irrigated it is estimated that it will be worth $75 per acre, making a property value of at least $35,000,000. The Idaho Mining and Irrigation Company, the capital stock whereof is largely owned in New York City, has constructed an important series of irrigation works. The chief one is known as the New York Canal. This canal in its first division is to be double in capacity to the great Erie Canal, the latter being but 70 feet wide at the top and only 7 feet deep. The Idaho "New York" Canal for 30 miles will be 12 feet deep and 81 feet wide, with a grade of 2 feet to the mile. The starting point is in a cañon 12 miles above Boise where the river emerges from the mountains. The lava bluffs on either side give the requisite solidity for the head-gate works. The first 12 miles will cost in all $230,000. The land to be irrigated there does not exceed 1,000 acres. The canal has been brought out on high lines, bringing under water it is asserted at least 450,000 acres. The Phyllis canal belonging to the same company is planned to supply water to some 35,000 acres. These figures are controverted by others. The total cost of the Idaho Company's works so far are not less than $1,100,000. It is assumed that besides the irrigated lands a large amount of hydraulic power will be accumulated, so that factories and mills can be established. The canal may also be used for floating lumber. The works are of the most substantial character and present some novel features, especially in the way of drawing the sediment off from the canal, destroying the silt therein, so as to prevent the ditches from being filled by sediment. The mode of gauging water for sale, introduced by Capt. A. D. Foote, C. E., will be utilized in these works. The cost per acre for the first year is to be $2.50, after which the cost will be 5 cents per miners' inch for each twenty-four hours.

Since these reports were made a considerable interest has been aroused by the striking of artesian water at Boise and Moscow. At the close of September, 1890, there were twelve artesian wells in operation 2 miles from Boise at an elevation of 180 feet above the town, and at an altitude of 2,280 feet above sea level. The last eight wells are 45 feet in depth and water was struck at 40 feet. Rising above the surface the daily flow is now estimated at 750,000 gallons. There are four other wells in the vicinity, a little deeper and with about the same proportionate volume. Another well is being sunk at Fort Boise but water in sufficient volume has not yet been reached. The town wells at Moscow, 3 in number, are about 90 feet deep with a bore of 2½-inch diameter, having a flow for the three wells of 56,000 gallons of water per hour. The flow of these wells named is over 1,300,000 gallons per 24 hours. Water can be obtained below the surface at a depth of from 50 to 100 feet. Quite a number of artesian wells in this county are being used for the irrigation of lawns, gardens, and orchards. At Boise the water companies owning the wells advertise to irrigate the orchards and vegetable gardens thereof. The evidence is abundant that in Idaho, as elsewhere in the arid region, there may be found a large supply of underground waters. The discussion of the past year has attracted close attention to this subject. An estimate made of the water supply in sight, before the Senate committee, is as follows:

	Cu. ft. per second.
Flow of Snake River (at Eagle Rock)	5,000
Flow of Salmon River (in Cassia County)	1,820
Flow of Boise River	6,000
Flow of Payette River	1,000
Flow of Weiser River	180
Flow of Big Wood River	154
Flow of Raft River	745

On the table lands, in the spring of the year, are many natural lakes or ponds; some of these are perennial, others having a depth of from 3 to 5 feet disappear, with the advance of the season, indicating that depth of evaporation and seepage for three months. From the last rivers the water runs right into the lava and keeps sinking. In the Big Lost River it runs down on the cañons and after awhile it is all exhausted. That whole country is one system of sub-storage. The water from Camas Creek, Bingham County, also loses itself in the desert and rises again in the range of lakes along the line of Idaho and Montana.

Value of ditches, etc., in several counties of Idaho.

[Per last Territorial report of Governor W. L. Shoup, 1889-90].

Counties.	Assessed value of improvements on lands.	Assessed value of patented lands.	Number of acres.	Assessed value of irrigating canals.	Assessed value of mining ditches.
Ada	$1,229,841	$841,267	136,800	$39,125	....
Alturas	50,550	27,214	16,886	....	$4,027
Bingham	208,595	325,434	117,148	†650,000	....
Bear Lake	162,300	100,127	208,330	a73,500	....
Boise	64,845	39,725	10,701	1,100	51,360
Cassia	86,765	153,710	48,224	3,528	....
Custer	196,290	....	25,780	8,430	5,996
Elmore	48,385	49,616	20,360	370	5,996
Idaho	95,870	192,673	97,961	....	3,900
Lemhi	170,585	47,719	12,029	e40,000	e50,000
Logan	115,037	107,785	85,364	1,500	1,000
Oneida	163,831	212,531	53,132	21,560	....
Owyhee	125.510	54,222	55,628	15,000	1,850
Washington	92,715	463,520	48,022	5,400	3,000
Total	2,811,119	2,616,543	926,365	850,513	127,129

There are eight artesian wells at Boise, four serving that place, having 11 miles of water pipes.

Divide Idaho by counties, and we shall have the following concise statement of facts showing their relation to irrigation, present and perspective.

Ada County.—Every surface and nearly every spring that can be utilized for irrigation is now under surface. Outside of the Boise and Payette River systems, there are about 100 miles of small ditches. The large streams furnish the main supply for the farmer's use. At the beginning of 1890 there were 36 ditches, having a length of 308 miles, with 30 miner's inches of water taken from this stream. In all there are 62 complete ditches, having a total length of 408 miles, in this county. Two hundred and seven of these miles are impressed in three systems.

Alturas County.—There are 268,000 acres of arable land, of which 14,500 acres are arid and under ditch. Of the total area 21 per cent is estimated as reclaimable. Only 5.13 per cent are now under ditch. The county had, in January, 1890, 10 ditches, 18 miles in length with a carrying capacity of 1,700 miner inches.

Bear County.—This is one portion of the Mormon settled region. Small farms are the rule. Irrigated and under ditch are 21,500 acres; available for reclamation 40,000 acres; 35.5 per cent of the reclaimable land is now utilized, under the Mormon system of small farms and ditches. The average area of the farms will not exceed 7 acres. With a length of 206 miles, there are 69 canals.

Bingham County.—Also settled by the Mormons, has 284,750 acres irrigated and under ditch; 10 per cent of the reclaimable land is now irrigated. In all, 2,503,500 acres can be brought under cultivation. The ditch mileage is 517, divided into 86 primary canals and ditches.—A. D. Foote, C. E. of Boise, sends the following tables:

Bingham County, Idaho, 1890.

[Reported by A. D. Foote, C. E.]

Name of canal.	Source of water supply.	Locality.	Total length (miles).	Length, first section (miles).	Bottom width (feet).	Grade per mile (feet).	Length, second section (miles).	Bottom width (feet).	Grade per mile.	Remaining section (length).	Bottom width (feet).	Grade per mile).	Total cost.
Rexburg	Teton River	Bingham Co.	11	6	12	2½	5	8	5	6	16	4	$8,000
Westfield	do	do	7	2½	13	2½	2	8	5	2½	8	4	3,000
Fall River and Teton Canal.	Falls River	do	10	2	30	5½	2	30	15	6	30	10	10,000
Teton	Teton River	do	9	4	14	2½	5	10	2½	...	...	...	5,000
St. Anthony	Henry's Fork	do	20	6	30	2½	6	20	7	8	10	7	12,000
Consolidated Farmers.	do	do	10	6	30	4	4	12	2½	...	...	...	6,000
Cedar Hollow and Foot Hills.	South Fork Snake	do	25	13	40	7½	13	30	7½	...	...	...	...
Idaho	Snake River	do	43½	12	40	1½	23	30	2	8½	30	6	75,000
Porter	do	do	9	9	30	2	...	...	...	...	...	...	50,000
La Belle	South Fork Snake	do	5	5	25	...	...	...	...	...	...	...	16,000
Farmer's Friend	do	do	14	14	18	...	...	...	...	...	...	...	10,000
Eagle Rock and Willow Creek.	do	do	50	15	30	6	16	20	6	19	15	6	100,000

Name of canal.	Amount paid in cash.	Remainder paid in labor.		Amount it could be contracted for at present time.	Work begun in—	Work finished—	Water first used—	Amount water claimed* (miner's inches, 4-inch head).	Owned by—
		Men per day.	Teams per day.						
Rexburg	$1,000	$2.00	$4.00	$8,000	Mar., '83	June, '83	May, '83	5,000	Corporation.
Westfield	200	2.00	4.00	3,000	— '85	May, '88	May, '88	2,500	Private parties.
Fall River and Teton Canal.	500	1.50	3.00	...	July, '89	— '90	...	50,000	Corporation.
Teton	300	2.00	4.00	5,000	— '83	— '83	June, '83	5,000	Do.
St. Anthony	800	1.50	3.00	12,000	July, '88	May, '89	— '89	20,000	Do.
Consolidated Farmers.	1,000	1.50	3.00	6,000	Oct., '88	— '90	May, '90	5,000	Private parties.
Cedar Hollow and Foot Hills.	...	...	...	...	Sept., '88	...	...	50,000	Corporation.
Idaho	75,000	...	...	75,000	June, '89	— '90	— '90	100,000	Do.
Porter	50,000	...	...	25,000	— '85	— '86	— '86	10,000	Do.
La Belle	4,000	2.00	4.00	15,000	June, '87	Unfinished.	— '88	25,000	Do.
Farmer's Friend	3,000	2.00	4.00	10,000	— '87	June, '90	Aug., '88	...	Do.
Eagle Rock and Willow Creek.	50,000	3.00	6.00	75,000	— '80	— ,90	— '80	...	Do.

*Claim recorded in Blackfoot.

NOTE.—In addition to these canals the following works in Bingham County are under way in part belonging to the extensive system devised for storing and distributing the head waters of the Snake River. They are: Upper and Lower Liman canals, from south fork of Snake River, having a length of 14 miles (7 each); length of first section, 7 miles; width at bottom, 12 feet; grade per mile, 5 feet. Three canals (Texas Slough, Salem, Woodmansee) from Teton River; two of 10 miles each in first section, 20 feet in width, one of 27½ and the other 5 feet grade. the third canal having length of 3 miles, a width of 20 feet, and a grade of 2½ feet. Four canals from Falls River (Full River, Anderson, Kern, and McBee), one of 12 miles, first section, 20 feet deep and 10-inch grade per mile; three having 3 miles, estimated, with 6 feet for one and 10 feet depth of the other two, and a grade of 2½ feet per mile. Three canals from Henry's Fork (Birch, Egin, and Mason), one of 6 miles, one of 15, and one of 3; having width of 15, 26 and 8 feet; two having grades of 2½ and one of 76.10. One from Leigh's Creek (Buckner Ridge) with 6 miles length, 12 feet width, and 10 feet grade per mile. Canon Creek and canal, 16 miles, 12 feet width, 5½ grade per mile.

Number of canals as reported	28
Mileage of canals as reported	3,221½
Total cost of twelve canals	$295,000
Total cost of twelve canals as reported, in cash (balance in labor at from $1.50 to $3 per day, according to Mormon usage)	$185,000
Amount of water claimed—	
In miner's inches per second as reported	322,500
Cubic feet	6,450
In gallons	41,573.6

Bingham County, Idaho, 1890—Continued.

Legal name of corporation or association.	Controlled by—	Officers in charge distribution.	No. shares ownership divided into.	Shares issued.	Remaining shares held by—	Par value shares.	Selling value shares.
Rexburg Irrigation Canal Co	Directors	Superintendent and water master.	2,000	800	Company.	$10.00	$10.00
Westfield Canal Co	do	Water master.	12	12	....	250.00	250.00
Fall River and Teton Canal Co	do	do	2,000	1,000	Company.	10.00	10.00
Teton Canal Co	do	do					
St. Anthony Canal Co	do	do	....	....	....	....	....
Consolidated Farmers Canal Co	do	do	....	....	....	50.00	50.00
Cedar Hollow and Foothill Canal Co.	do	do	2,500	500	Company.	30.00	30.00
Idaho Canal Co	do	do	5,000	5,000	....	100.00	100.00
Porter Canal Co	do	do					
La Belle Irrigating Co	do	do	....	....	....	....	....
Farmer's Friend Canal Co	do	do	12,500	4,000	Company.	5.00	5.00
Eagle Rock and Willow Creek Canal Co.	do	do	4,000	4,000	....	25.00	25.00
Total shares as reported	....	....	28,012	14,312	....	....	....

Legal name of corporation or association.	Shares furnish water for—	Amount annual assessment, share.	Cash or worked out.	Day work, 10 hours, man.	Day work, 10 hours, man and team.	Area of arable land under canal.	Area actually watered.	Area in alfalfa and clover.
	Acres.					*Acres.*	*Acres.*	*Acres.*
Rexburg Irrigation Canal Co	5	$1.00	Cash, 80 cts. balance.	$1.25	$4.00	5,000	2,000	400
Westfield Canal Co	200	20.00		1.25	4.00	2,400	600	200
Fall River and Teton Canal Co.	10	5.50	....	1.50	4.00	40,000	5,000	1,000
Teton Canal Co	....	....	....	....	....	2,000	1,500	300
St. Anthony Canal Co	10	5.00	....	1.50	4.00	30,000	5,000	1,500
Consolidated Farmers Canal Co	....	....	....	....	....	5,000	2,000	500
Cedar Hollow and Foothill Canal Co.	10	....	....	....	....	125,000	....	....
Idaho Canal Co	10							
Porter Canal Co	....	....	....	....	....	100,000	Few.	....
La Belle Irrigating Co	2	.50	Cash	....	....	5,000	510	200
Farmers' Friend Canal Co	....	....	....	....	....	4,000	800	200
Eagle Rock and Willow Creek Canal Co.	5	3.75	....	2.00	4.00	15,000 25,000	3,100 10,000	500 4,000
Total	....	....	....	....	....	358,400	22,570	8,800

Bingham County, Idaho, 1890—Continued.

Legal name of corporation or association.	Area in other hay, grasses.	Area in wheat, oats, etc.	Area in common vegetables.	Area in orchards.	Irrigation season begins.	Irrigation season ends.	
	Acres.	*Acres.*	*Acres.*	*Acres.*			
Rexburg Irrigation Canal Co.	150	1,000	400	50	Apr. 20	Oct. 1	From A. S. Anderson, Kaintuck, Aug. 30, 1890.
Westfield Canal Co	20	300	70	10	Apr. 20	Oct. 1	Do.
Fall River and Teton Canal Co.	1,000	2,500	400	100	Apr. 20	Oct. 1	From A. S. Anderson, Kaintuck, Aug. 28, 1890.
Teton Canal Co	100	900	140	60	Apr. 20	Oct. 1	Do.
St. Anthony Canal Co	100	1,000	1,400	100	Apr. 20	Oct. 1	Do.
Consolidated Farmers Canal Co.	400	1,000	80	20	Apr. 20	Oct. 1	Do.
Cedar Hollow and Foothill Canal Co.	......	......	......	......	......	......	From E. P. Henry, Eagle Rock, Aug. 31, 1890; not completed.
Idaho Canal Co	......	......	......	......	......	......	From Joseph A. Clark, Eagle Rock. Aug. 30, 1890.
Porter Canal Co	200	200	100	10	May 1	Sept. 15	Do.
La Belle Irrigating Co	200	300	90	10	May 1	Sept. 15	From W. H. B. Crow, Eagle Rock, Aug. 29, 1890.
Farmers' Friend Canal Co.	200	2,000	300	100	May 1	Sept. 15	Do.
Eagle Rock and Willow Creek Canal Co.	1,560	4,000	500	......	May 1	Sept. 15	From Joseph A. Clark, Eagle Rock, Aug. 30, 1890.
Total	3,820	13,200	3,480	460	......	......	

Boise County.—The total area irrigated or under ditch is 83,500 acres. It is claimed that 26,200 acres can be reclaimed by the supply of water in sight. There are in the county 20 ditches; total length, 60 miles.

Cache County.—Has under ditch and irrigated 82,000 acres; estimated as irrigable, from the valuable water supply, if stored, 655,000 acres. There are 298 farm canals and ditches, with a total length of 299 miles, a remarkable illustration of the small farm system of the Mormon population.

Custer County.—Has 24,000 acres irrigated and under ditch, and claims 446,000 acres as reclaimable. The ditches are all small and individual in character.

Elmore County.—There are 10,000 acres under ditch and irrigated; 230,000 acres can be reclaimed and served by the water supplies of the county. In this county there are 50 ditches with a total length of 25 miles.

Idaho County.—Irrigation is not generally used. Some small ditches for both farm and manufacturing purposes have been constructed. There are a considerable number of bored and driven wells within the county. They are used chiefly for stock and domestic purposes. The valley land, it is claimed, does not need irrigation. On the opposite side of the river, in Washington, water is raised by centrifugal pumps and distributed for irrigation purposes over the land, similar to those in use in Idaho County.

Kootenai County.—Is one of the northern sections of the Panhandle region. Very little irrigation is practiced in the southern portion of the county; it is considered unnecessary. The granite nature of the soil, however, precludes ditch construction to any great extent. It will probably be supplied by underflow sources.

Latah County.—Also belongs to the semihumid area of Idaho. The only irrigation practiced here at present is that involved in the use of artesian water for lawns, orchards, and garden purposes. There are probably between 100 and 200 low-pressure wells in the county, showing the possibility of obtaining a much larger supply.

Lemhi County.—Has 10,000 acres underditch and irrigated. It claims 600,000 acres as irrigable. The ditch surface is confined at present to the valley lands of the Lemhi, Salmon, and the small lateral tributaries thereof. The length is 300 miles in 250 ditches.

Logan County.—Has reported 50,000 acres under ditch or irrigated, and claims 1,250,000 acres as reclaimable. The chief source of supply are the two Wood Rivers. The mileage of ditches in connection therewith is about 120; 140 miles of ditches have been constructed on the famous Kamas Prairie, which, with similar full systems, will make 300 miles in all.

Nez Perces.—There is only one ditch reported in this county, and the use of the water for irrigation is only incidental. A considerable supply can be obtained from phreatic sources.

Oneida County.—Reported 38,800 acres under ditch or irrigated, with 148,000 acres that can be reclaimed. Storage reservoirs are claimed as necessary for this region. A large canal project to carry water from the Bear River in Bingham County is also under consideration. There are 65 ditches, with a length of 100 miles.

Owyhee County.—Reported 21,300 acres in process of irrigation and under ditch, with a reclaimable area of 248,500 acres. There are 66 ditches of 153 miles in length within the county.

Washington County.—Reported 40,000 acres as under ditch or irrigated, and claims 500,000 acres as irrigable. The Weiser River supplies 270 farm ditches and one county ditch of 12 miles in length. There are 5 important canals in the neighborhood of the Weiser with a length of 40 miles, and its tributaries of about 80 miles. Its slopes cover nearly 15,000 acres. This is a great fruit region. Each occupied and cultivated homestead will have 5 acres devoted to fruit. The total length of Washington ditches will be not less than 290 miles.

The future of the State of Idaho, from an irrigation standpoint, is among the brightest within the arid domain. Its prospects warrant all the efforts that are being made, and its citizens are proving themselves among the most enterprising in this direction of the entire Northwest.

Of districts and enterprises in the State under the most active development during 1891, some reference is given, which while it does not cover all that deserves notice, presents those of which the office of irrigation inquiry has some definite data.

The Idaho Falls Canal is situated in Bingham County, Idaho, taken out of the Snake River, 22 miles northeast of Idaho Falls, is built in a southwesterly direction, extending to the Blackfoot River, making the canal 45 miles in length. The canal is 40 feet on the bottom, 3 feet deep, 2 feet slope, berme banks 3 feet, top banks 5, capacity 455 cubic feet per second. The first branch leaves the main canal 1¾ miles from head gate, and is 12 feet wide on the bottom, 2 feet deep, with a capacity of 140 cubic feet per second. The main ditch is completed 8 miles from head gate; first branch is completed 5 miles, with 26 miles of farm laterals; proof has been made on some 14,000 acres tributary to this first branch. The second branch will leave main canal 11 miles from head gate, and be 38 miles long, 16 feet on the bottom, 3 feet deep, 2 feet slope, berme banks 3 feet. Land tributary to main ditch and laterals, 57,000 acres. A large construction force has been constantly employed, and the managers expect to have their system completed in June, 1892.

The Great Western Canal system, comprising two canals, is in the same county, and is owned and operated by a construction company so named, with headquarters in Chicago. This system has a capacity of 640 cubic feet of water per second, and will furnish water for irrigating 115,000 acres of land. These two canals, one called the Great Western and the other Porter ditch. The former takes its water from the west bank of the Snake River, opposite Bear Island, 11 miles north of Idaho Falls, has head gate of solid masonry 100 feet wide, 71-foot openings for water, with foundation in the rock bottom of the river. A large dam is thrown across the river 1¼ miles below the head gate, raising the water to the surface. Directly above the dam is placed the second head gate that controls the water in the canal, consisting of eight gates 6 feet wide and 7 feet deep. This canal is 40 feet wide on the bottom with a capacity of 450 cubic feet per second; its total length south and west down the valley will be 58 miles. The Porter ditch takes its water from the Snake River, 2½ miles north of Idaho Falls, has a strong wooden head gate, is 25 feet wide on the bottom and has a capacity of 190 feet per second. It has been in use for five years, and main canal is 8 miles long with 30 miles of branches. The total number miles of completed ditches are: Main, 20 miles; branches, 40 miles; of farm laterals, 50 miles; delivering water in 1891, on 8,000 acres of land. It is intended to complete the system by October, 1892.

One of the most notable of the new irrigation systems now in progress is that under the management of the "Boise City and Nampa Irrigation, Land and Lumber Company," whose source of supply is the Boise River, the water for which is taken some distance below the dam of the Idaho Canal Company at a point 5 miles above Boise. The initial point of the extensive system now growing was made in the purchase of the "Ridenbaugh ditch," 9 miles long, and carrying a small volume of water taken from the Boise River, 5 miles above Boise. This, with the rights, was sold to the Idaho Central Canal and Land Company, who, considering it a poor investment, disposed of it to its present owners, who, eighteen months ago, organized under the name of the Boise and Nampa Irrigation, Land and Lumber Company, with a capital of $1,000,000. Taking this ditch as a basis, the system within a year has been extended into one of 100 miles of main and 153 miles of lateral ditches, which, with a chain of ten lakes and reservoirs for storage, completely cover the Boise and Deer Flat valleys, together with all the intervening table-lands. Without the construction of a dam at its point of diversion (which frequently involves an outlay of $100,000) the water comes from the Boise at the rate of 3½ feet per second, in a canal 45 feet wide at the top, 22 at the bottom, and 6 feet deep, taking a third of the river's volume at low water. The main ditch is 12 miles long, two branches going through the Boise Valley, each 25 miles in length, and one, the Nampa branch, extending 41 miles through the Deer Flat Valley.

There was a good deal of practical skill and sagacity displayed in the selection of the point at which the water is tapped. The old ditch has been enlarged and extended, while new highland canals of considerable size have been constructed along the ridges, so as to insure every advantage of gravity, and, what is still more important, to warrant the utilization of a number of natural lake beds and depressions along the canal routes which, at comparatively moderate cost, can be utilized for reservoirs. Two of such basins are in operation; one at Nampa, the point of railroad junction on the Oregon Short Line with the branch road to Boise, 18 miles distant; the other is 3 miles distant from Nampa. One of the proposed lakes will serve 30,000 acres, and the others cover areas of from 5,000 to 15,000 acres each. The engineering importance of this enterprise is found in the adoption of this plan of open tableland reservoirs.

The section under the Nampa system is even more favorably located for such a purpose than that of northeast New Mexico, to which references have elsewhere been made. On the whole the climate is more genial, while the whole of the Boise Valley is under control of the "Chinook" or warm winter winds of the Pacific northwest. Without attempt to proclaim any theories or advocate a special system, the personal observation and close study of the special agent in charge leads distinctly to the conclusion that American enterprise is developing in connection with such irrigation works as those already operated on the Maxwell Grant, in New Mexico, the system under organization and construction at Nampa and in the Boise Valley, and the very boldly devised and executed works along the Bear River, in North Utah (Cache County), with others that are projected, methods of utilizing natural conditions for water storage, conservation and management that are practically new in character and promise large results in both safety and service, as well as in the great economy of construction and administration they will achieve. Mountain and high altitude channel storage holds great danger within their lines; storage of the table-land character under review can, with reasonable strength of embankments, be readily made safe, while the advantages for service, etc., are very much greater. There would necessarily be under such a system, as that of the Nampa Company, a much less degree of construction cost attached to river, cañon, or mountain reservoir system, requiring heavy masonry or earth and rubble dams, and there must also be provided a costly system of service ways, head gates, flumes, etc., capable of resisting flood tendencies. The economy of the table-land system of reservoirs appears to be in the fact that the mountain streams and sources by which they are to be supplied can be conducted to the reservoirs, one on the open plain at a comparatively small cost, and with works of a simple character. The silt carried down may be handled easier and cheaper if necessary by means of settling basins, from which the cleared water can be drawn to other reservoirs. Again, the need of obtaining a sufficient fall of gravity pressure compels the adoption of high ridge lines, and consequently brings a larger area "under ditch" and earlier reclamation. All of these points are well exemplified in the Nampa system, which will bear close study by irrigation organizers and constructors. Another point as to this section is seen in the possibility of easy drainage. Much of the area to be served by the system is underlaid at a short depth from the alluvial surface by a larger of hard volcanic tufa, from a few inches to a couple of feet in thickness. In the making of their canals the company have often been obliged to blast through this thin strata. It was pointed out that its existence indicated the possibility of great economy of water and the early need of systematic drainage. The surface soil will quickly fill up, and the surplus will run off swiftly. The contours of the principal area to be served are such (except the Deer Flat section, which is open mesa or plains-land having an easy fall to the west) as to insure the collection of drainage waters, and their return to the irrigation channels at a small cost and by means of low-lying open ditches in which the drainage can readily be collected.

The Boise and Fayette valleys are excellent fruit-growing sections; probably second only to the coast counties of California below San Francisco Bay for the production of prunes. The soil of these valleys is a decomposed lava and very rich in all the requirements of vigorous plant life. All the cereals, clover, timothy, and alfalfa, and nearly all kinds of temperate fruits, like apples, pears, peaches, prunes, as well as all the smaller fruits are grown abundantly here, and roots grow to perfection. Watermelons attain prodigious size, and the right conditions exist for the successful culture of the hop vine.

Farms and orchards in the Boise and Fayette valleys and on Deer Flat are in proof of the remarkably productive power of southwest Idaho, and in all reasonable probability of the adjacent sections of eastern Oregon. With the Missoula and Bitter Root valleys in Montana, and the Walla Walla and other sections of eastern Washington, the whole of southwest Idaho will become a region of great horticultural importance. The Nampa Company served during 1891 about 13,000 acres, of which nearly 10,000 are under the old Ridenbaugh ditch. In 1892, this service will be nearly or quite double in extent.

The increase in horticultural activity in this section is shown by the statement made to the special agent that one nursery firm had sold within the year 80,000 trees, prunes, pears, plums, etc. On every hand the evidences of activity were visible and the movement along the northwest routes surpasses in activity and extent even that of the southwest. As land is held at more moderate rates and there are still large areas of public land to be settled upon, the general immigration shows a younger and hardier class, one to whom "climate" has not been a paramount condition.

There are a large number of other enterprises in Idaho, showing the active interest felt in agricultural reclamation there. Among these is an enterprise of importance, which is to derive its support from the Snake River. The lands to be irrigated are located in Logan and Cassia counties, in the central and southern part of the State, and its construction will add a new and large area to the field of irrigation, for it would surely be followed by other efforts. The river dam, by which the needed water is to be diverted, is built at Mendoca, Idaho, near the railroad crossing and just above the point where begins the great lava bed, through which the Snake River for so long a distance cuts a turbulent pathway. The main ditch is to be 45 miles in length, and 85,000 acres lie on the north side of the river and 15,000 acres on the south side. The significant engineering point in this work is the fall of the river, which is 7 feet per mile above the dam and 30 below it. The proposed canal begins at the dam site at an elevation of 37 feet below low-water line, and follows the rim of the lava bed all the way to Starr Ferry. The amount of land that can be irrigated on the south side will increase in the ratio of 1,000 acres to every 1 foot in the height of the dam. In order to secure this increase, the south side canal will have to be moved to higher lines than they are now run upon. On the north side of the river nothing will be gained by increasing the height of the dam, for here the lava shuts off all the increase; a 30-foot dam covers all the land below the rim of the lava. The variation between high and low water is about 12 feet. The length of the dam between the abutments is 527 feet. The apron will be built in 12 by 12 timbers. The cost of the dam is $133,150, and the canal on the north side is 32 miles long to the point where it enters the river again. On the south side it will be 12 miles long, and three-quarters of this will be excavated through lava. The ditch is 40 feet wide and 10 feet deep at the dam. The cost is estimated as follows:

Canal	$215,000
Dam	133,150
	348,150
Engineer expenses	56,000

In addition to the 100,000 acres to be irrigated, there are, under the projected canals, 225,000 acres that only require a cut of a mile and a half through the mountains to irrigate.

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers to circulars received by this office:

ADA COUNTY.

Caldwell (post-office), Howard Sebree (September, 1891):

Has cleared and improved farm of 300 acres, irrigated by water from a canal 23 miles long, with capacity of 20,000 cubic inches to serve 20,000 acres; estimates cost per acre of clearing and preparing sage-brush land for irrigation and cultivation at $3 (his system does not require plowing). One dollar and fifty cents per cubic inch is the average rental of water per annum. One half of a cubic inch per acre is sufficient after land is once irrigated. Perpetual water rights are assessed 25 cents per cubic inch for annual repairs.

Products successfully raised by irrigation and yield per acre of same: Wheat, 30 to 50 bushels; corn, 40 bushels; oats, 40 to 80 bushels; all other small grain; apples, peaches, pears, prunes, plums, cherries, and other fruits, etc.

Falks Store (post-office), Edson Bishop (September, 1891):

Water supply: Payette River.

Irrigation works: Ten miles main ditch; numerous laterals; main ditch 8 feet wide on bottom, 14 feet wide on top. One main headgate; about thirty small ones; five waste gates.

Cost per mile of ditches: Main, $1,000; laterals, $200. Cost per acre from $3 to $10. Cost per acre for annual maintenance and repairs, $1 to $2.

Average cost per acre for preparing land for cultivation by irrigation: For sage-brush land, to clear, grub, level, and seed it down, nearly $20.

Cost of water supply to user per acre, $2 (annual rental, $2).

Area under ditch, 2,000 acres; under cultivation, 200 acres.

Chief products: Wheat, oats, hay, sugar cane, hops, fruit, potatoes, beets, etc.

Average annual yield per acre: Wheat, 20 bushels; oats, 50 bushels; hay, 5 tons; potatoes, 100 to 250 bushels; all other crops not produced sufficiently to estimate.

Boise City (post-office), A. D. Foote (September, 1891):

Idaho Mining and Irrigation Company (system not completed, but it is proposed to include storage of about 250,000 acre-feet of water; one canal (Phillis) completed; others only partially); water supply, Boise River.

Area under ditch, 25,000 acres; under cultivation, 2,000 acres.

Mileage and size of ditches, 55 miles; 24 feet at top, 12 feet at bottom, 6 feet deep; grade, 2 feet per mile; one head gate; reservoirs not yet built.

Cost per mile of ditch, $3,000; average cost per acre, $4.

Average cost per acre for annual maintenance and repairs, $2 (including interest on cost of works).

Average cost per acre for preparing land for cultivation under irrigation: Clearing, $2; plowing, $2; fencing, $1; ditches on land, $1; total, $6.50.

Cost of water supply to user per acre, $2.50; annual rental cost, $2.50.

Chief products: Hay, cereals, potatoes, and fruit.

Value of annual product per acre, $25.

Boise City (post-office), Joseph Perrault (September, 1891):

Water supply: Walling Canal, Boise River; appropriation, 100,000 inches; oldest water right on river built in 1864.

Works: 7 miles main canal; first mile, 60 feet on top, 50 feet on bottom; other 6 miles, 10 feet on bottom, 15 feet on top; 2 head gates.

Area under ditch, Boise City and 2,000 acres of land outside, all of which is under cultivation (extension proposed to reach 50,000 acres).

Cost per mile of ditch, about $7,000; cost per acre, about $5.

Average cost per acre for preparing land for cultivation under irrigation, $5; grazing, $2.50.

Average cost per acre for annual maintenance and repairs, about $1.

Average cost per acre of water supply to user, $4.

Annual rental, for lots 50 feet by 122 feet, $5 per season.

Staple products under irrigation, wheat, rye, oats, barley, corn, potatoes, alfalfa, timothy, clover, apples, pears, plums, prunes, peaches, and small fruits.

Average annual yield per acre: Wheat, 40 bushels; rye, 25 bushels; oats, 50 bushels; corn, 60 bushels; potatoes, 400 bushels; alfalfa, 6 tons; timothy, 2 tons; clover, 6 tons.

Nampa (post-office) J. M. Jones (September, 1891):

Boise City and Nampa Irrigation, Land, and Lumber Company.
Water supply, Boise River; area under ditch, 100,000 to 150,000 acres; under cultivation, 10,000 acres (first year after completion of canal).
Irrigation works: Total mileage of ditches, 250; 103 miles of main ditches; at head gate, 22 feet at bottom; 38 feet wide at water level; 3 main ditches; 16 feet wide on bottom; 4 main head gates.
Number and area of reservoirs: 5 reservoirs—(No. 1) 15 acres; (No. 2) 120 acres, 16 feet average depth, dam 420 feet; (No. 3) 50 acres, average depth 9 feet, dam 600 feet; (No. 4) 320 acres, average 16 feet deep, dam 400 feet (this lake is 2 miles long); (No. 5) 230 acres, 12 feet deep, dam 200 feet long.
Cost per mile of ditches: Main ditch, $4,000; laterals, $200 to $2,000; cost of reservoirs, etc., $20,000; cost per acre for farm laterals, 50 cents.
Average cost per acre for preparing land for cultivation: For clearing sage brush, $3; plowing, $1.50.
Average cost per acre for maintenance and repairs, 15 cents (with perpetual water right); annual rental per acre per annum, $1.50 (without water right).
Products under irrigation: Wheat, oats, barley, rye, alfalfa, clover, timothy, potatoes, and other vegetables—apples, pears, prunes, peaches, plums, quinces, berries, etc.
Average yield of products per acre: Wheat, 25 bushels; oats, 50 bushels; barley, 40 bushels.

Payette (post-office), The Payette Nursery and Fruit Farm (per W. G. Whitney, December 9, 1891):

Water supply, Payette River; irrigation works in neighborhood.
Three ditches: (1st) Settlers' Ditch, 16 feet wide on bottom, 20 feet top, 7 miles long; (2d) Stevenson Ditch, 8 feet bottom, 12 feet top, 15 miles long; (3d) Lower Payette Ditch, 12 feet bottom, 16 feet top, 8 miles long. A head gate for each ditch; no dams on rivers; several new ditches under construction; cost per mile, about $3,000 (cost depends upon the size of ditch and nature of soil, etc.).
Area under ditch, 80,000 acres; under cultivation, 10,000 acres.
Cost of water supply to user per acre, $1.50; annual rental cost, $1.
Average cost per acre for preparing land for cultivation (under irrigation), $10.
Average cost per acre for ditches, etc., $1.
Average cost per acre for annual maintenance and repairs, about 25 cents.
Products under irrigation and yield per acre: Alfalfa, 9 tons; clover, 8 tons; wheat, 40 bushels; oats, 80 bushels; potatoes, 500 bushels. All kinds of fruits yield abundantly. Average value of product per acre, $40 net profit.

Payette (post-office), A. B. Moss & Bro. and Payette Valley Bank (September, 1891):

Lower Payette Ditch (appropriation, 100,000 inches).
Water supply, Payette River; area under ditch, 8,000 acres; under cultivation, 4,000 to 5,000 acres.
Works: Eight miles of main ditch, 12 feet on bottom, 20 feet on top, 4 feet deep. (Proposed extension of 13 miles.) Two main headgates, 40 lateral gates; no other works.
Cost per mile of main ditch, about $2,000; average cost per acre for main ditch, $2; for laterals, $1; cost per acre for annual maintenance and repairs, $1.
Average cost per acre for preparing land for cultivation under irrigation, $10.
Cost of water supply to user per acre, $1. (All users of water own shares in ditch.)
Chief products under irrigation: Hay, fruits, grain, and vegetables.
Estimated value of products per acre: Hay, $30; fruits, $300; grain, $25; vegetables, $100.

Nampa (post-office), James A. McGee, president of board of trade (January 20, 1892), in an address to the board, stated as follows:

The enterprises we have started have been the means of increasing the value of over 200,000 acres of land between Boise and Snake River from $1.25 to at least $10 per acre without water, and on an average of at least $25 with water; or from a value of $250,000 to $2,000,000 without water, and to a value of $5,000,000 with water.

The assessed value of the whole county has been increased 200 per cent.

BINGHAM COUNTY.

Blackfoot (post-office), D. M. Cappo (September, 1891):

Corbett Slough Ditch. Water supply, Snake River. Area under ditch, 5,000 acres; under cultivation, 3,000 acres.

Works: Twelve miles of main ditch. Capacity, 7,000 inches. Size, 22 feet at top, 14 feet at bottom, at its head, and lessens gradually to 6 feet at the terminus. No reservoirs. Two headgates. Laterals or private ditches taken out along the whole length of main ditch.
Cost of ditch per mile, about $350; cost per acre, about $1.50.
Average cost per acre for preparing land for cultivation under irrigation, from $5 to $15; for grazing, about half of this.
Cost per acre for annual maintenance and repairs, about 10 cents.
Cost per acre of water supply to user, $2.
Chief products: Hay, grain, potatoes, and other vegetables, fruit of various kinds, melons, etc.
Value of products per acre: Estimates that "crops costing $5 to $8 per acre will bring from $20 to $25 per acre."

[Area under cultivation under this ditch will be doubled next year.]

L. E. Hall (Salt Lake City, Utah), "President Idaho Canal Company:"

Water supply, Snake River. Area under ditch, 25,000 acres (estimated); under cultivation, 1,000 acres.
Irrigation works: Twelve miles main canal, 40 feet on bottom; two branches, 23 miles and 7 miles long, 30 feet each on bottom. Loose rock dam at headgate, 15 rods long, 3 feet high. One main headgate composed of 7 separate gates, each 8 feet wide, giving 56 feet space for opening for water; headgate of solid masonry laid in cement, rock piers; 6 waste gates; 6 large culverts under canal; other works, flumes, bridges, etc.
Cost per mile of canal: Main line, $5,000; branches, $1,500.
Cost of headgate, $6,000; culverts, $4,000; waste gates, $2,000; bridges, $3,000; right of way, $5,000. Canal not completed. Cost given as far as constructed.
Average cost per acre of works, ditches, etc., $5.
Average cost per acre for preparing land for cultivation under irrigation, $5.
Average cost for annual maintenance and repairs, 75 cents.
Cost of water supply to user per acre, "not determined; 12½ cents at present."
Annual rental cost, 75 cents at present.
Chief products: Wheat, oats, barley, hay, and potatoes.

[Data for county generally, compiled from answered circulars sent to Senator F. C. Dubois, Martin Patrie, T. J. Smith, and others.]

Water supply, Snake and Blackfoot rivers and tributaries.
Area under ditch, variously reported; generally estimated that 75 per cent of agricultural area of county is under ditches or canals either constructed or in progress of construction, and about 40 per cent under cultivation.
Irrigation works: Three large canals under construction, Market Lake and Butte Canal, Idaho Canal, and Great Western Canal; from 75 to 150 miles main canal from 25 to 50 feet on bottom; very many smaller or private ditches; 8 headgates (main), smaller ones numberless.
Cost per mile of canals or ditches, from $200 to $10,000; cost per acre, from $3 to $8.
Average cost per acre for preparing land for cultivation under irrigation, about $6.
Cost per acre for annual maintenance and repairs, about 25 cents to 75 cents.
Cost per acre of water supply to user, from $3 to $8; annual rental cost, from 25 cents to $1 per acre.
Chief products: Wheat, oats, barley, some corn, alfalfa, timothy, potatoes, prunes, pears, apples, cherries, strawberries, and all small fruits.
Average annual yield per acre: Wheat, 25 to 35 bushels; oats, 40 to 50 bushels; potatoes, 200 to 300 bushels; alfalfa, 5 tons; timothy, 2 tons.

Eagle Rock (post-office), John F. Shelley, secretary and treasurer, Eagle Rock Willow Creek Water Company (November, 1891):

Water supply, Snake River. Area under ditch about 40,000 acres; under cultivation, about 10,000 acres.
Irrigation works: 50 miles main canals and laterals, two main canals, 20 feet and 30 feet on bottom, respectively; two headgates in river.
Total cost of canal, etc., $100,000; annual rental cost of water, 50 cents per acre.
Average cost per acre for preparing land for cultivation under irrigation, $5; for irrigation works, ditches, etc., $4; for annual maintenance and repairs, about 50 cents.
Chief products: Wheat, oats, alfalfa, timothy and blue grass hay, potatoes, and other vegetables.
Yield per acre: Grain, about 40 bushels; potatoes, about 300 bushels.

Idaho Falls (post-office), secretary Great Western Canal Company:

Water supply, Snake River, main channel. Area under ditch, 50,000; under cultivation, perhaps 500 acres.

Irrigation works: 50 miles ditch, 30 feet on bottom (except for the first mile from the head, which is 40 feet), 45 feet at top; two headgates; no reservoirs or dams.

Cost per mile of ditch, about $3,000; cost per acre, about $3.

Average cost per acre for preparation of land for cultivation under irrigation, about $5; cost for annual maintenance and repairs per acre, about 25 cents.

Products: Wheat, rye, oats, barley, potatoes, timothy, and alfalfa.

Estimated value of annual product per acre, $20 net.

CASSIA COUNTY.

Basin (post-office), A. B. Roberts (September 19, 1891):

Has 960 acres under ditch 500 acres under cultivation.

Water supply, Willow Creek; capacity, 300 inches (mountain stream, fed by melted snow).

Irrigation works, 2 miles of ditch, 2 feet wide at bottom; 1 headgate (to guard against floods); a distributing gate; "ditches in neighborhood generally made by plowing a few furrows, then running a V-shaped scraper through it."

Cost per mile of ditch, $2.50; average cost per acre, 8 to 10 cents; average cost per acre for preparing land for cultivation (under irrigation), about $2 (including leveling); for grazing no irrigation is used.

Cost of water supply to user per acre, 5 cents; annual repairs, $1 (on whole ditch).

Staple products and yield per acre: Alfalfa, 6 tons (2 tons for each cutting); wheat, 30 bushels; oats, 35 bushels; barley, 35 bushels; potatoes, 250 bushels.

Water service estimated at less than 10 inches for 100 acres. The waters of all the small brooks and springs is appropriated; dams and reservoirs needed for irrigation on a proper scale.

[The Spring Basin Water Company, of this vicinity, have 4,500 acres under ditch, about 1,000 acres under cultivation; cost for annual repairs not more than $20; for distribution, $150 annually—wages of water master.]

Thatcher (post-office), George Chapin (September, 1891):

Water supply, Goose Creek; capacity, June 1, 7,000 inches; September 1, 1,000 inches; area under ditch, 1,000 acres; under cultivation, 360 acres.

Irrigation works, main canal, 14 miles long; average width, 8 feet; depth, 3 feet; fall, 7 feet per mile; capacity, 1,000 inches; headgates, 1 for main canal and 1 for each lateral; no other works.

Average cost per mile of main canal, $100.

Average cost per acre of irrigation works, ditches, etc., in vicinity, $1.

Average cost per acre for annual maintenance and repairs, 25 cents.

Average cost per acre for preparing land for cultivation under irrigation, $3.

Average cost per acre of water to user, 50 cents (per annum).

Staple products: Wheat, oats, barley, rye, potatoes, and all garden vegetables raised in Northern States, alfalfa and timothy hay, large and small fruit.

Average product per acre: Wheat, 30 bushels; oats, 45 bushels; barley, 40 bushels; rye, 25 bushels; potatoes, 250 bushels; alfalfa, 6 tons; timothy, 3 tons.

ELMORE COUNTY.

Mountain House (post-office), C. P. Oliver (September, 1891):

Water supply for irrigation is pure spring water coming out of granite formation; no extended system of irrigation in neighborhood; ditches from spring, which carries about 160 inches water; 3 headgates; has 100 acres under ditch; 60 acres under cultivation; area under ditch by other neighborhood systems, 300 acres.

Average cost per acre for preparing land for cultivation (under irrigation), $10.

Average cost per acre for preparing land for grazing (under cultivation), $5.

Average cost per acre for irrigation works, ditches, etc., $7.50 (for large tracts.)

Average cost per acre for annual maintenance and repairs, about $1.

Staple products: Hay, grain, vegetables, and all kind of fruit raised outside of tropical climate.

Estimated yield per acre and value: Hay, 6 tons; grain, 60 bushels; potatoes, 400 bushels; fruit yield worth about $150 per acre (except peaches, which are worth much more).

[Geo. P. Hall (of Mountain House, this county) states that "this vicinity is a good field for developing artesian water."]

LOGAN COUNTY.

Bellevue (post-office), John Hailey (September, 1891):

Has 100 acres under cultivation with irrigation; about 2,000 acres under ditch in neighborhood.

Average cost for preparing land for cultivation under irrigation: For clearing land having growth of sage brush, willows, etc., about $5 per acre; fencing, 50 cents per rod.

Average cost per acre for irrigation works, ditches, etc., about $5.

Average cost per acre for annual maintenance and repairs, $1.50.

Staple products: Wheat, oats, barley, alfalfa, timothy, and native grasses, potatoes, cabbage, and other garden vegetables in common use.

Yield per acre and value of same: Wheat, 25 bushels, 75 cents per bushel; oats, 35 bushels, 50 cents per bushel; barley, 30 bushels, 60 cents per bushel; potatoes, 150 bushels, 40 cents per bushel; alfalfa, 4 tons, $5 per ton; timothy, 2 tons, $8 per ton; native grasses, 1 ton, $6.

OWYHEE COUNTY.

Silver City (post-office), L. J. Pritchard (September 19, 1891):

Water supply of neighborhood, creeks having generally an abundance of water until June or July each year.

Irrigation works: Ditches averaging 1 mile in length, 2 feet wide on bottom, depth varying, but running as much as 9 feet deep; dams about 5 feet high; head gates for each ditch and lateral; all ditches, etc., owned by water users. (No reservoirs.)

Cost per mile of ditches, about $120; cost of dams, about $30.

Cost of water supply to user per acre, $5.

Average cost per acre for preparing land for cultivation under irrigation: For clearing land of sagebrush, greasewood, etc., $4; plowing, leveling, etc., $6; total, $10.

Average cost per acre of ditches, etc., about $5.

Average cost per acre for annual maintenance and repairs, about $1.50.

Products, yield per acre, and value: Wheat, 30 bushels; barley, 40 bushels; oats, 45 bushels; hay (principally alfalfa), 7 tons; vegetables, and fruit; average value of crop per acre at present prices, about $30.

Average area under each ditch, 60 acres; under cultivation, 30 acres.

WASHINGTON COUNTY.

Weiser (post-office), T. C. Galloway (September, 1891):

Water supply: Weiser River, abundant supply in early spring months; fails generally by July 1 each year.

Irrigation works: Canal (or ditch) 17 miles in length; width, 16 feet on bottom at upper end, 5 feet at lower end; dam, 4 feet high; 2 head gates, 7 waste gates, 1 flush gate, 4 flumes, each 100 feet long; capacity of ditch (1891) 3,000 inches; 40 per cent lost by seepage, etc.

Cost per mile of irrigation works, $2,000 (not yet completed).

Average cost per acre of works, ditches, etc., from $1 to $10.

Average cost per acre of preparing land for cultivation (under irrigation): For clearing out sagebrush, etc., $2; plowing, $2; leveling, $6.

Average cost per acre for annual maintenance and repairs, about $1.

Area under ditch by this or neighborhood system, 5,000 acres; under cultivation, 2,000 acres.

Chief products: Wheat, corn, oats, barley, alfalfa, sorghum, potatoes, beans, and other vegetables and fruits.

Yield per acre: Grain, about 30 bushels; hay, 1 to 5 tons; potatoes, 300 to 400 bushels; beans, 500 bushels.

[Water sold for $1 per acre under this system.]

CENSUS FIGURES FOR STATE.

The United States Census Office (Bulletin 157) reports for this State (Mr. F. H. Newell) as follows for the year 1889:

Number of counties	18
Number of irrigators	4,323
Total acreage irregated and in crops	217,005
Average size of farms in acres	50
Average value of products per acres	$12.93

MONTANA.

This State lies between the meridians 104 to 116 degrees of longitude west from Greenwich, and the parallels of north latitude 45 degrees, 15 minutes to 49 degrees. Its average breadth is 275 miles and its greatest length by northeast and southwest is 540 miles. It contains 143,776 square miles or 92,016,000 acres of land. It is bounded on the north by British America, on the east by North and South Dakota, on the west by Idaho, and on the south by Wyoming and Idaho. In area, Montana is the third largest State in the Union, being surpassed in extent only by Texas and California. One-third of its extent consists of high mountain ranges which form the northern portion of the Rocky Mountains, and in which lie the sources of the Missouri River system. The western slope of these ranges is marked by large tributaries of the Columbia flowing to the Pacific Ocean. Approaching Montana from the eastward the land gradually rises about 8 feet to the mile, until Livingstone, in the center of the State and at the eastern base of the Belt Mountains, is reached. The average altitude of the State is not over 3,000 feet. The higher ranges will rise from 6,000 to 7,000 feet above sea level, and the loftiest peak in the State obtains an altitude of 11,000 feet.

Montana is among the best watered States on the continent, its river system being of the largest order, comprising the Upper Missouri basin formed by the confluence of the Gallatin, Madison, and Jefferson rivers, all rising in the higher ranges of the northern Rockies. The Upper Missouri has a course of 500 miles within the limits of the State. The Yellowstone, its principal tributary, has a similar course and carries a body of water equal to that of the leading stream. On the north, the chief feeders of the Missouri are the Milk, the Marias, and the Sun rivers, and on the south, the Yellowstone and Musselshell. The principal tributaries of the Yellowstone are the Powder, Elk, and Big Horn rivers. West of the Rockies the drainage runs into the Clark fork of the Columbia. In the extreme northwest the Kootenai and the Bitter Root drain that important section, making two of the most valuable valley regions in the State. Numerous other tributaries are confluent on either side of the range with these larger streams. Everywhere they form fertile valleys, broad mesas, and high table or plateau areas, making of Montana one of the most important pastoral regions. Though the streams and rivers are numerous, the hydrography of Montana is very simple in character. On the east it is all comprised in the Missouri basin, and on the west in that of the Columbia. There are many mountain lakes and basins, which must form at no distant day available reservoirs for the great storage supplies that will be required in the reclamation of some 20,000,000 or 25,000,000 acres of arable land. The hydrology of Montana is such as to warrant the statement that a larger proportion of its great area can be brought under irrigation, and made to produce in abundance all the grains, grasses, fruits, and vegetables of the temperate zone than is the case with any other section of the arid region.

The largest mountain lake is known as the Flathead, a beautiful body of water, 30 miles long by 10 wide.

The chief characteristic of Montana in regard to climate is its dry and bracing atmosphere. Like all arid regions, the temperature is better than its latitude would indicate. Towards the northwest the lowering of the mountain ranges admit of the passage of the famous "Chinook" wind, bringing in its passage from the Pacific the warm breath of the Japanese current. Heavy snows very often disappear in one night under the influence of the "chinook." The thermometer's range is about the same in winter as that of northern Iowa and Wisconsin, but the weather is much more endurable, and the average is warmer. The summer heat, though warm, is never excessive, and the nights are always cool. The sheltered mountain valleys in summer and winter are more endurable than the open plains, especially to the eastward. The low range mountains which permit the passage over their summits of the moisture-laden winds of the Pacific Ocean act as condensers, so that their summits in winter are laden with heavy snows, and in summer gather rain, with the full force of the eastward-moving moisture. A considerable proportion of Montana, especially in the north, is claimed to be semihumid in character, owing to the early summer rains, but even there the benefits of irrigation in making positive security for agriculture is fully acknowledged, and large enterprises of that character are under way. In the central and southern portions of the State, as well as eastward through the great open valleys of the Yellowstone and Upper Missouri, irrigation is a direct necessity. Its application insures crops, according to the testimony before the Senate Committee, of from three to ten times in value, in quality, and in quantity, of products of same character raised in the central and eastern States.

The higher mountain region is well timbered, and when going westward, the trees belong chiefly to the Pacific coast varieties and the evergreen family. They are usually of a great size and valuable for merchantable lumber. On the eastern slopes, while the trees in the timber belt grow to a great height and density, the trunks are not usually large. Several varieties of the pine comprise the great body of this timber. Along the Missouri and the Yellowstone, with their principal tributaries, are found large amounts of cottonwood, box elder, and ash. The table and bench lands are treeless. The timbered area is estimated at about 36,000 square miles.

The soils of Montana are generally of the best quality, largely formed of the mountain débris, being both granitic and volcanic in character. They range from heavy clay to light sand, but consist principally of a dark or chocolate-colored loam. The best soil is found on the *mesa* or bench land just above the valleys and rising to the base of the mountain ranges. Probably no better wheat land exists on the continent than these same mountain plains. Wheat has been cultivated for twenty years past, yielding from 30 to 40 bushels per acre, and showing no diminution. The grain is always heavy and the yield is astonishing. In the Gallatin Valley, where farming has been carried on for the longest period, 40 bushels to the acre has been a usual crop since settlement began. In the Little Belt Basin oats are raised weighing 45 pounds to the bushel and producing 85 bushels to the acre.

In the valley of the Yellowstone at Glendive, Miles City, and Billings, it was stated, in testimony taken by the Senate committee, that from Livingstone to the mouth of the Yellowstone the valley area alone embraces 765,000 acres of reclaimable land. Corn will produce 30 bushels to the acre; wheat, 45 to 50; potatoes, 450 bushels; alfalfa grows 6 tons to the acre yearly; and that all the small berries and fruit trees of the temperate zone can be grown successfully. With irrigation all crops would be secure, and their yield largely increased. With a proper storage system it is assumed, and on reasonable grounds, that about 8,000,000 acres of bench lands could be reclaimed by means of high-line ditches. The general feeling in eastern Montana is favorable to that form of irrigation enterprise. Nearly the whole of the higher table lands can be made available for the cultivation of root crops and of forage plants, thereby insuring a rapid change from cattle ranch to cattle farm. The Gallatin Valley has been cultivated for more than twenty years, producing large crops continually. The testimony shows that an average crop per acre of potatoes would be 400 bushels; of oats, from 30 to 60 bushels; of wheat, 40 bushels; of barley, from 50 to 100 bushels, or an average of 75 to the acre. This is the result of irrigation. Without irrigation the yield is two-thirds less per acre. Irrigation begins in the last of May or the first of June. In this valley the irrigation enterprises have heretofore been of the ordinary community character, projected and constructed by the farmers themselves. Large enterprises are now under way, which will probably greatly increase the acreage under ditch and rapidly advance the economy of water use. In the Judith Basin, the Teton and Sun River valleys, a considerable area has been brought under cultivation. The bench lands of the two rivers are from 400 to 500 feet above the valley bottom, and it has a slope towards the Missouri of 100 feet in 6 miles. The soil is warm, with sand enough in it for fertility, underlaid with gravel so as to insure good subsoil drainage; the frosts on these lands are never early in the fall or late in the spring. The blue-joint grass, peculiar to Montana since population went in and cultivation begun, grows abundantly there and makes the finest hay in the State. Mr. H. M. Wilson, engineer of the U. S. Geological Survey, estimates that there are 700,000 acres of excellent land that can be readily reclaimed. Thirty-five to 40 bushels of wheat are produced to the acre; also, 4 tons of blue-joint hay and 3 of timothy can be raised to the acre. Fruits and berries grow rapidly and well.

The Society of Civil Engineers in a report to the Senate committee, declared that 1,000,000 acres or but one-ninetieth part of the State is now irrigated and cultivated. The possible area of reclamation was estimated at 20,000,000 acres. The area reclaimable without a system of general storage would not exceed 3,000,000 acres. Such a system of storage in their opinion can not be constructed without the aid of State or national government. The high table lands having a general altitude of 3,000 feet are largely reclaimable; but the problem of water storage and distribution for such lands involves great expenditure and a high degree of engineering skill and enterprise.

The underflow and artesian water problems have heretofore attracted but little attention in Montana. Such wells as have been bored in the Yellowstone Valley are of considerable depth and their pressure and flow are not great, but everywhere may be found at moderate depths a supply of negative artesian water, rising nearly or quite to the surface, and even now forming a valuable supply for stock and domestic purposes. The enormous volume of precipitation that falls upon the ranges of Montana does not all, it is evident, find its way through the surface channels to the great Mississippi Valley and thence into the Gulf. The indications all point to a considerable absorption of this precipitation by the earth itself. This phreatic supply will on further investigation be found both large and accessible.

Messrs. W. W. De Lacy and W. C. Childs have given interesting statements from the standpoint of underground supply. Mr. De Lacy said that where gravel was found underlying the surface coil there was a great tendency of the mountain streams to disappear as they reached the bench lands. He said:

> A great many of our streams are running dry alternately; that is to say, there will be a stream of water for a mile or two, then it will sink, and then it will reappear. When that is the case, they are generally on a loose gravel bed. I think the reason of that is the water percolates through the gravel and disappears, and then for some reason comes up again. * * * The water is generally found at bed rock, and its depth from the surface differs with the depth of the bed rock. In a great many of the streams that are apparently dry I think that reservoirs could be built by sinking a dam down to bed rock. Frequently you will see a stream that is in a little cañon of perhaps 100 yards or so, and the stream may be dried up at either end of it, though having water above. I think if a well were put down to bed rock the water would be forced up and there would be a reservoir, and a very convenient one.

Mr. Childs, of Helena, is a farmer on a large scale and of recognized ability. In the sections where cultivation was claimed to be successful without irrigation, he has said that water would be found within a foot or two of the surface. "In my belief," said Mr. Childs, "if you dig 7 feet anywhere you will find standing water. Such water is found on the bench lands. It seems to be a sheet of water underlying the whole bench land area. It does not rise when tapped, but appears to remain at the same level continuously."

Mr. Childs described the manner in which he utilized a natural spring by boring immediately behind its outflow, thus increasing the same. The natural flow was about 5 inches of water. On sinking the bore to the depth of 160 feet he has obtained a flow of 200 gallons per minute. A 3-inch pipe was put in and the flow continues at 13 inches above the ground. Mr. Childs declared that he knew it to be true that flowing water could be found beneath the beds of so-called dry streams. At the time of the committee's visit he was engaged in digging a bed-rock drain in a channel 2,000 feet above the stream that supplies his ditch. The evidence showed there had been a loss of water by sinking of 25 miners' inches. From the results then achieved he expected to obtain a flow of 150 inches of bed-rock water, a supply fully as great as that of the normal surface flow. In Mr. Childs's opinion, then, this is true generally of mountain streams.

Mr. G. C. Swallow, inspector of mines, described a stream in the Judith Mountains known as the "Dry Wolf." In a portion of its course it flows 500 and for several miles 800 miners' inches of water. This water then disappears. Mr. Swallow believes that it could be restored to the surface by means of a bed-rock dam. Evidence could be multiplied on this point, but it is not necessary as the general topography is abundant proof of the probability of finding phreatic waters all over the State of Montana, and at a reasonable depth below the surface. It remains true, however, that the storage-reservoir system will finally be the one on which Montana must largely depend.

Of the sixteen counties in the State of Montana nearly all of them have considerable areas of land that could be made available by irrigation for agriculture. Dawson County, in the extreme northeast, having an area of 25,650 square miles, with but 50,000 acres now under cultivation, claims the possible reclamation, by means of water in sight, of some 4,000,000 acres. The county is watered both by the Upper Missouri and Yellowstone River systems. The latter stream passes through the southeast corner of the county, and most of the cultivated area lies in the valley thereof. At Glendive there are four ditch systems having about 60,000 acres under them. There are five wells in the vicinity of Glendive of considerable depths, the water of which rises nearly to the surface; it is then raised by windmills and used for stock and domestic purposes. It is estimated that 4,000,000 acres can be reclaimed in this county. North of the Yellowstone Valley there is no cultivation, except small patches for ranch purposes, until you reach the Milk River Valley. The Upper Missouri flows generally within cañons from Fort Benton, until it leaves the State at Fort Buford. The Milk River Valley, now being opened by railroads, is considered to be an excellent agricultural region. Water is obtainable from the streams and by means of underflow, the water plane being but a few feet below the surface. Accurate data as to the mileage of irrigating ditch is not obtainable, because in most cases they are simply small farm works of which no record is made. The Glendive works are supplied by water from Spring, Cane, and Fox creeks, and of the four irrigation works begun in that vicinity the main canal is 4½ miles in length, with 5 miles of lateral ditches, four dams, four head gates and two weirs. Its cost was $2,500. Many springs are utilized for garden irrigation.

Custer County, south of Dawson, and occupying the balance of the plains section of Montana, has an area of 32,300 square miles. It contains, also, the Crow Indian and Cheyenne reservations. Considerable activity in irrigation is seen in the neighborhood of Miles City. Nearly 100 miles of main canal are in operation, divided among some thirty different systems. The lateral or farm canals will have a length of 125 miles. There are thirty-five to forty dams, and the same number of head gates. One ditch, 20 miles in length, cost $100,000. The total cost of irrigation works is estimated at over $200,000, serving about 100,000 acres of land. On the Tongue River a canal has been constructed serving 16,000 acres of land at a cost of $60,000. Two steam pumps have been erected at Miles City, on the banks of the Yellowstone, and are now used to lift and distribute water for irrigation purposes. The crops raised are principally hay, oats, corn, potatoes, and garden vegetables. The largest area is laid down to grass and the making of hay. The cost of service is $1 per acre. Irrigated land ranges in value from $35 to $50 per acre, unimproved land, without water, from $5 to $7. Small berries and fruit trees grow well, and several score acres are now under cultivation. The valley of the Yellowstone within this county comprises at least 400,000 acres of reclaimable land. With the bench-lands and table-lands 3,000,000 acres can be put under ditch and cultivated. The area of reclaimable land within the Crow Reservation, which is also in this county, is estimated at 1,500,000 acres. This is watered by the Yellowstone and its southern branches. There are twenty-four artesian wells within a radius of 15 miles of Miles City. Their depths range from 150 to 500 feet with bores of from 1½ to 3 inches. They flow above the surface with considerable pressure. About 300 acres are now irrigated by the water of these wells in parcels of from 2 to 25 acres each. Water can be found without flow at a depth of about 50 feet, and it is easily obtainable upon the mesa or bench lands. Over 100 wells of this character are in operation within the same radius as the artesian wells referred to. Windmills are used for pumping purposes. A considerable quantity of the water from both classes of wells is used for hay lands, but the main use is for domestic and stock purposes. The first artesian well was sunk in 1884 and still flows with undiminished pressure. Springs are largely utilized for garden and grass land.

Yellowstone County, to the north of the river, has an area of 2,390 square miles. It is estimated that 500,000 acres can be supplied from the Yellowstone and Musselshell. The bench land between the two streams lies from 200 to 300 feet above the valley, and the fall to the eastward is such as to render the taking out of water by high-line canals a work of easy engineering. In 1889 there were five large enterprises under way, with a length of 70 miles. The area then irrigated was about 20,000 acres. One of the ditches has been extended 17 miles and is now 27 miles in length. By another work, 25 miles in length, 50,000 acres were under ditch in 1890. Water can be obtained at from 15 to 20 feet below the surface, and stock is generally supplied by such wells. The soil of this county is quite rich, and the levels are such as to render it easily irrigated by gravity. Nothing can be grown without irrigation, and water is needed wherever crops are raised. Wheat yields from 25 to 40 bushels per acre, oats from 50 to 70, and potatoes from 300 to 400 bushels.

Choteau County, in the extreme northern part of the State, and embracing the head waters of the Upper Missouri and Milk rivers, is now developing a considerable area of irrigated land by means of canals supplied by the Teton and Sun rivers. Fifty thousand acres are now estimated as under ditch and cultivation, and 5,000,000 is given as the limit of the reclaimable land. The valley of the Milk River, in the extreme, north, forms a valuable body of agricultural land. It has been advertised widely as cultivatable without irrigation, but settlers who have gone on do not find that to be the fact. Indeed it can not be too clearly borne in mind that within the arid region all land to be fit for cultivation must have access to water either by artificial application or from natural subirrigation sources. Throughout this region, wherever necessity has compelled experiment, phreatic waters have been reached at a depth of from 5 to 20 feet below the surface. The principal irrigation enterprise in the southern part of Choteau County, and in connection with Cascade County, is the Sun River Canal and its branches. This is located at its head in Choteau County, and is expected to furnish an irrigation supply for 276,480 acres lying between the Teton and Sun rivers, north and south, and the Missouri and Rocky Mountains, east and west. In illustration of the farming value of northern Montana the following statement is given:

> R. P. Menefee, a prominent farmer, reports in 1889 the sowing of 5,665 pounds of wheat and the thrashing out of 5,515 bushels, weighing 209,580 pounds, or very nearly 37 pounds harvested to each pound sown. In 1890 Mr. Menefee reported 5,600 pounds of oats sown, the harvest yielding, when thrashed, 5,318 bushels, or 186,130 pounds; that is not quite 37 pounds return to each pound sown.

The works in progress in the section of which Great Falls is the business center show the irrigation demands of a region so far north. The Teton Canal is 18 feet wide at bottom, 25 feet at top, carrying 4 feet of water, has its source at the base of the mountains, on the north fork of Sun River, and runs east over high prairie land between the two streams. The completed Teton Canal branch is fed by that river, 2 miles from base of the Rocky Mountains. It runs east through a plateau known as Teton Lake Basin, thence 6 miles to head of Big Muddy Creek, using it as a water bed for several miles, thence by a lateral ditch 25 miles long, with twenty sublaterals covering over 40 miles in length, supplying a large tract from Choteau to Sun River, west of Great Falls in Cascade County.

Probably the most important branch is that being constructed in the latter county, having Benton Lake for a reservoir. This is 7 miles long and from 3 to 5 miles wide, and contains a great body of water. An abundant supply is insured, as the unfailing Teton River can through the canal so named be easily turned into the lake. This is tapped by a cut 1¼ miles long, and 45 feet deep; 500 feet of this cut was "sluiced" out in one week by means of a 40-horse power engine, pumping 500 gallons per minute. From the mouth of this cut two canals are being constructed, 20 miles of which are now dug, and which when completed will be 40 miles in length and be feeders for over 60 miles of lateral ditches; all will be completed for irrigation next season.

Cascade County, lying south of the center of Choteau County, shows great activity in irrigation, as will be seen by the works in progress there. Its area is 2,570 square miles. There is under ditch and irrigated some 50,000 acres. The reclaimable area is estimated at 600,000 acres. Over 100 miles of main ditch are now in operation in the county. This county is a point of great interest, owing to the appearance, in the neighborhood of Great Falls, of huge outcroppings of the Dakota sandstone. The foothills of the Rocky Mountains trend to the northwest and throughout Cascade and Choteau Counties are from 8° to 10° of longitude farther west than is elsewhere the case along the whole range. The appearance of the Dakota sandstone outcroppings at Great Falls is regarded by Department geologists as a positive proof of the conclusion which they have reached, that the vast artesian basin of the Dakotas and eastern Montana is supplied mainly by the drainage of the Rocky Mountains. The measurements made in 1891 by Chief Engineer Edwin S. Nettleton, of streams and springs above Great Falls, and of the river below them, show a great loss of flow between the two points, clearly illustrating the disappearance of a large surface supply by absorption in the sandstone at this point.

Canals now constructed have cost $500,000, and, including laterals, have a length of nearly 500 miles. The following are some of the leading works: Cascade Land Company, main ditch, 45 miles, 12 to 16 feet wide at top, carries 3,000 miner's inches, and will irrigate 3,000 acres. Sun River works, 12 miles long, cost $2,000 per mile, carries 3,000 inches, and irrigates 3,000 acres. The Crown Butte Canal, 26 miles in length, cost $3,000 per mile, carries 25,000 inches, will irrigate 210,000 acres, and has one reservoir, costing $25,000. Chestnut Valley ditch is 12 miles in length, and carries 15,000 inches. There are two other ditches, one 5 and the other 7 miles long, and several score of small farm and neighborhood and farm ditches. Three large projects are now under survey and are to be constructed during 1892.

Fergus and Meagher Counties in the central and eastern part of the State embrace large areas of cultivatable land, the waters for whose reclamation will be supplied from the tributaries of the Upper Missouri and the Musselshell. Fergus County has an area of 7,415 square miles; Meagher County, one of 1,760 square miles. It is claimed that 150,000 acres are now under fence and ditch in Fergus County and 30,000 acres in Meagher. The famous Judith Basin lies within the borders of Fergus County. It is a region of excellent agricultural capacity. No large irrigation enterprise is found in either county. The ditches are mainly small affairs taken out by individual farmers from the many mountain streams that abound therein. The reclaimable area is put at 2,000,000 acres.

Park County, to the south of Meagher and north of the Yellowstone National Park, has an area of 4,740 square miles. About 15,000 acres are under fence and ditch, cultivated by means of irrigation. The surface of the county is mountainous. The principal industry is mining. The Yellowstone Valley contains the largest proportion of irrigable lands, and there are numerous small valleys that can be brought under irrigation. It is claimed that 500,000 acres can be so utilized.

Gallatin County is now the most important agricultural region in Montana. Over 100,000 acres are under ditch and cultivated. Water therefor is supplied by the East and West Gallatin rivers, Middle Creek and its branches, on the east, and from the west by the Madison and Jefferson rivers. Gallatin Valley is well cultivated. Irrigation works are usually small, having been constructed by individual farmers. Several large canals are now in process of construction, and the facilities for distribution will be greatly extended during 1891. The East and West Gallatin canal, 25 miles in length, carries 8,000 miners' inches. The Middle Creek ditch carries 2,000 miners' inches. Other canals now in construction are taking water from the West Gallatin and Madison rivers. Underground water is obtainable by wells at no great depth. It is estimated that 400,000 acres will be reclaimed. The cost of irrigation is about $1 per acre annually. The foothills of the mountains surrounding the Gallatin Valley will afford an excellent locality for the cultivation of the fruits of the temperate zone. Bozeman and the region around it have been under continuous cultivation for nearly thirty years, and the grain and root crops continue now as heavy as when the land was first cultivated.

The most important irrigation area within the borders of Montana is that embraced within the Gallatin Valley, of which Bozeman on the Northern Pacific Railroad, is the thriving center. Mr. C. A. Gregory, a former citizen of Chicago, who has had considerable irrigation experience in New Mexico and is now resident in the Gallatin Valley, sends the office of irrigation inquiry in response to questions sent him, quite a full statement of irrigation conditions here. Mr. Gregory's intelligence, his knowledge and personal reliability in such matters is known to the special agent in charge, and there is no hesitation in presenting here what Mr. Gregory says under date of December 10, 1891:

> You ask many questions and the details of these would require months of investigation to answer quite accurately. I will give you an honest summary, the result of observation and inquiry, and mainly in the order of your inquiry. I do not spare pains to answer you. I despair to give you perfect figures, but I will at least avoid the error of overstatement, even to gratify the pride of this valley, rich enough and prosperous enough as it is, when fairly stated.
>
> The mileage of private farm ditches in the Gallatin Valley, *i. e.*, the cultivable portion of Gallatin County, Mont., it would be exceedingly difficult to give. Some attempt, however, must be made in order that a stranger to the situation may form a tolerably correct idea of the extent of irrigation in this locality.
>
> Hundreds of miles of private farm ditches exist. These come out of some twenty or more creeks and streams, including the East Gallatin River, a small feeder to the West Gallatin, which latter is a strong mountain stream of heavy fall to the mile and of large capacity of flowage, elsewhere stated; so that portions of more than a dozen townships are supplied, more or less, with irrigation facilities, and some thoroughly. This valley may be roughly said to be four townships wide by five townships long, mainly sloping, with undulations from south to north, with counter slopes from the circumference; everywhere surrounded by mountainous country, which is indented with deep cuts or cañons on the easterly and southerly borders, from which issue permanently-flowing streams. From all these streams, except the West Gallatin River, every drop of water is conducted into small and large private farm ditches, and utilized for irrigation. From the West Gallatin River, also, many ditches are taken for farm use; and from this river alone are taken out the three large canals owned by incorporated companies, named in order of time of construction, the West Gallatin Canal Company, the West Gallatin Irrigation Company, and the Excelsior Canal Company, elsewhere further described.
>
> By far the greater part of the water of this river runs to waste. It is many times in its flowage the volume of all the water taken into its tapping ditches.

Rocky Cañon Trestle and Flume. The Gallatin Valley, Montana.

There are no reservoirs of water in this valley from which conserved waters are drawn. Up the Bozeman Cañon there is Mystic Lake, some 14 miles from Bozeman, some 2,000 feet in height above this valley, where a dam 22 feet high is now being built to hold backwater, to be run down the natural channel of great and rapid fall, and then to be drawn off into ditches for foothill and bench land irrigation. The capacity of this pond may be understood from its size, about 1 mile long by one-half mile wide, and great depth may be secured.

The only land companies are the Manhattan Malting Company and the West Gallatin Irrigation Company, the latter constructing a large canal to supply water mainly to its own lands and grantees of its land, and still owning some 25,000 acres; the former owning 160 acres in town-site at Manhattan and some 10,000 acres for its own farming purposes, mainly for the cultivation of barley.

The West Gallatin Canal Company's ditch is 20 miles long, cost said to be about $60,000; built about three years ago; taken out of the east side of the West Gallatin River, well up to the cañon; carries about 8,000 inches, it is said; built with inexpensive headgate and wing sieve dam of no great cost.

The Excelsior Canal Company's ditch is 12 miles long; built in 1890-'91; cost about $40,000, as estimated, and built by syndicate of farm owners under it, supplying water to its stockholders only; carries about 8,000 inches, it is stated; built with slight structure of headgate and no dam.

The largest and most costly canal is that of the West Gallatin Irrigation Company, constructed 1890-'91, and at present some 24 miles in length, on a high line to cover bench lands; taken out of the west side of the West Gallatin River; still in process of extension in length.

In this connection it is not important to state the area cultivated under these canals separately. Under the two first-named canals the total capacity of the ditches is required for the ground under them, and such land is already mostly in cultivation; under the last-named ditch the lands are mainly new and unbroken, and are just brought into such relation to water as to be cultivable. There lie under this ditch, as it may be extended, 60,000 acres, being more than the ditch has capacity to supply with water.

With caution held out that an estimate must be considered something of a guess, we should say that under great and little ditches there are about 50,000 acres in cultivation.

The auditor's report for Montana for 1890 gives the number of ranches in Gallatin County at 460, and the acreage in ranches in Gatlatin County as 127,684 acres, and the ranches fenced as 115,374 acres. No scrutiny is made in these returns into the number of acres plowed. The acreage and the number of ranches have increased considerably since such figures were made up, and these figures are returns for assessment purposes only, and include railroad lands cultivated or uncultivated in the county. Much of such lands may not be cultivated. Such return is no index of what area is cultivated; let us go, therefore, to crop returns. The crop returns in auditor's report are not to be relied upon as coming up to the magnitude of area or yield per acre. We know individually of one tract of 1,200 acres now in cultivation, not embraced in 1890 year returns; we know of several tracts of 100 acres and upwards recently brought under the plow, not in such estimates. Fifty thousand acres are assumed as proximately the area in cultivation. We may see if this is tolerably correct by crop return. If you allow an average of 50 bushels to the acre in all kinds of grain, we shall have 2,500,000 bushels of grain, so that I think 50,000 acres a high acreage to state as cultivated, wheat, barley, and oats being the main crops; then consider the hay ranches worked upon, and not the natural grass ranches, and the vegetable and small fruit crops, and we may assume a yield of $1,250,000 in value. There are 35 thrashing machines here. These may be estimated as thrashing 60,000 bushels each on the average—certainly this is high enough to state it. This gives 2,100,000 bushels.

The average price of the three staples I place at an assumed figure, which I am advised is fair, and from this I get $1,250,000 as a year's yield in value. Any discrepancy in this result is certainly made up by considering hay and vegetables as included.

I furnish you a map of the Gallatin valley, and on it I place the three large canals and some of the lesser canal and marginal ditches, etc. To mark all the ditches would be to run out tortuous lines from every creek and river as thick as branches and their twigs from the main stem of a tree. A great fertile expanse, gridironed with circumfluent lines of ditches, bright and golden in harvest time with grain, and hay meadows in green for relief, and after harvest thick with stubble as a plush carpet is with its short, upreared filaments, is not an overdrawn picture of this valley.

Barley is great in yield and supreme in quality here; oats triumph in weight and measure to the acre, and wheat yield is as high in average as in any known region. You ask for the price of water. Water is not retailed here, but the price as understood by the canal companies is $2 per statutory inch as measured in accordance with the statutes of Montana—a poor method of measurement. This is a reasonable price.

The Gallatin valley is not alone the oldest cultivated valley, but it has been irrigated to a considerable degree. The average yield for a number of years (not less than twelve or fifteen) is as follows, and that, too, without any other fertilizer except water:

Wheat, per acre	bushels..	35 to 60
Oats, per acre	do....	50 to 90
Rye, per acre	do....	40 to 60
Barley, per acre	do....	35 to 60
Potatoes, per acre	do....	300 to 500
Hay, per acre	tons..	2 to 3

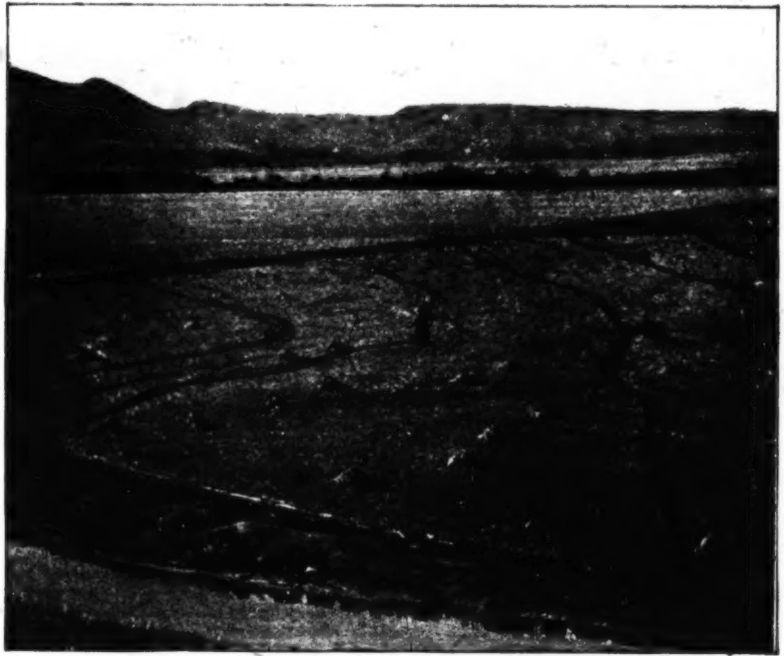
The annexed table refers to production during 1890, and will bear examination:

Name of farmer.	No. of acres.	Crop.	Total yield.	Yield per acre.
S. B. Cope	6⅓	Wheat, bushels	401	63⅓
Richard Blum	32	do	137½	43⅛
E. A. Selleck	8	do	398½	50
Rev. Mr. Bird	10	do	450	45
D. A. Kughen	47½	do	2,517½	53
Howell & Etheridge	160	do	6,950	43½
J. A. Howes	180	do	6,270	35
John Wilcox	97	Oats, bushels	4,100	42
L. W. Ours	25	do	1,926	77
F. Endres	30	Barley, bushels	1,760	58⅔
C. Bressler	40	Timothy, tons	65	1⅝
John Hanson	1½	Potatoes, bushels	400	266⅔
Charles Anceny	150	Alfalfa, tons	650	4⅓

Madison County, to the north of Brigham, in Idaho, with Gallatin, is the oldest-settled section of the new State. Irrigation is an absolute necessity for agriculture. The area of the county is 5,440 square miles. There are about 100,000 acres now under ditch, of which about one-third is cultivated to cereals and roots. Half a million acres, it is estimated, can be reclaimed. The water supplies are furnished by the Madison, Jefferson, and Ruby rivers. No large works have yet been constructed, all the ditches being small farm affairs. A great many mining ditches have been utilized for irrigation purposes in this county as well as those to the north of it lying within the Rockies.

Jefferson County, to the north of Madison, contains 2,060 square miles. The reclaimable area is estimated at 250,000 acres, and 25,000 acres are now under ditch and fence. The county is watered by Prickley Pear, McClellan, Beaver, Crow, and Hot Springs creeks, north and east, and by Boulder, White Tailed Deer, and Pipestone creeks on the south. Two ditches in Crow Valley have a capacity of 870 miners' inches. The area of land irrigated could be increased threefold by the supply of water now in sight, with due care of water and by proper works. In illustration of the value of irrigation in this high, mountain region, a report of the Boulder Valley Ditch, Milling, and Stock Company, organized 1875, shows that the enterprise began with one settler and 240 acres. There are now 1,000 settlers cultivating 4,800 acres. Before settlement the value of lands was $2.50 per acre. Its present value, improved with water supply, is $300; unimproved, $50 to $75 per acre. Land has no selling value without water. The duty of water is stated to be as low as 5 miners' inches per acre. The cost is $1.25 per annum. The crops grown are wheat, oats, barley, potatoes, cabbage, and other vegetables. Production per acre under irrigation is fully double that in the humid States.

Lewis and Clarke County, centrally located in the mountains, has



IRRIGATION BY CHECKS, GALLATIN VALLEY, MONTANA.

considerable irrigable area, with about 50,000 acres inclosed and under ditch and cultivation. There is estimated to be in the basins of Prickly Pear, Ten Mile, Seven Mile, and Sun rivers, with their tributaries, a large area of arable land that needs water to make it valuable. The entire area of the county is 1,769 square miles, of which 627 are valley and mesa land. Ditches take up all of the water flow from Seven Mile and Silver Creek. From the natural flow, 6 per cent of the Prickly Pear basin can be irrigated. There are thousands of acres in the Sun River basin, within this county, which could be reclaimed, if water was found and stored. Four per cent of this area is now under ditch. In Prickly Pear Valley, 6,000 acres are now cultivated. The Helena Ditch in this valley has a capacity of 1,000 miners' inches. Florence Canal, 23 miles long and nearly finished, irrigates about 15,000 acres. Another canal supplies 2,000 miners' inches. The Flat Creek Canal is 4½ miles long. The entire length of irrigation ditches in the county is about 100 miles.

Silver Bow County, 760 square miles in area and 5,000 feet above sea level, is devoted almost entirely to mining. It is rugged and mountainous. It is estimated that 40,000 acres could be reclaimed. The area under cultivation is small. Irrigated land is assessed at $100 per acre and sells at $150; nonirrigated sells at $5 per acre. There are many mining ditches in the Silver Bow Basin, which furnish water for small areas of arable land and could supply more. Some discussion has been had in this county over the practicability of obtaining artesian water. Under present knowledge the judgment is generally against its availability.

Beyond the range are found the two counties of Beaver Head and Missoula, occupying the north and south portion of the western flanks of the continental divide and receiving the benefit of the warm and moisture-laden passage winds from the North Pacific Ocean. The plants and timber of the North Pacific slope are found in this section of Montana. The trees are large and of the varieties known to the Pacific northwest. The precipitation is considerable and, but for the summer failure, would be sufficient for most agricultural needs. The southwest county, Beaver Head, has an area of 3,740 square miles. In 1889 and 1890 from 80,000 to 90,000 acres of meadow land were inclosed for flooding purposes. This area could be increased to 250,000. Beaver Head County is watered by Big Hole and Beaver Head Rivers, with their principal branches, Grasshopper, Rattlesnake, and Red Rock creeks. The valleys are low and narrow and the soil is alkaline in character. The bench or mesa lands are of prime quality, the soil being of rich loam, which when irrigated produces with great abundance. The artificial application of water is absolutely necessary. There were in 1889 three organized irrigation companies taking water from the Beaver Head River, and a large number of small farm and private ditches. Some activity has been manifested in 1890 looking to improved facilities and larger irrigation works.

Missoula County, the extreme northwest section of Montana, with an area of 9,580 square miles, embraces a large proportion of the best fruit land within the State. It will be the richest horticultural section. In 1889, 150,000 acres were reported as inclosed, under ditch, or cultivated. The total reclaimable area is estimated as 600,000 acres, but it is probably very much larger if water can be found for the service thereof. The streams by which the county is drained and served are branches of the Columbia system. The Bitter Root Valley, 35 miles in length and about 12 wide, with an average elevation of 3,000 feet, is admirably adapted for fruit culture. This is shown by the orchard region around Missoula City. The west side of this valley is well watered by mountain streams. The east side presents the appearance of an unbroken table land, cut by very few water courses, and requiring for its reclamation the storage of water. The entire valley contains a large area of first-rate arable lands. The orchards seen at Missoula in the early fall of the year when the fruit is ripe make a scene worth traveling many miles to witness. Universally the trees are so heavily laden as to require large props to sustain the weight of the ripening fruit on their branches. Fine agricultural lands are found in the valleys of the Missoula, Hell Gate, Flathead, Blackfoot, and other streams. The Flathead Indians have for many generations raised fine crops, and under the instructions of the Jesuit priests, who have been their teachers, are among the best farmers of their race. The Bitter Root Valley land requires, it is claimed, 1 inch of water per acre, running continuously for a few days at a time, and for two or three times during the growing season. On the west side of the Bitter Root there are a large number of small farm ditches, estimated at a total of 50 miles in length. Some twenty larger ditches have a mileage of 75 miles. They carry from 200 to 300 inches of water. With an improved irrigation system and greater economy of water nearly a million acres might be reclaimed, one-fourth of which would be valuable fruit land. Wheat produces 20 to 60 bushels, oats 30 to 110, pease 20 to 80, and corn 40 to 50 bushels per acre. Potatoes will average 350 bushels, and grow so large that they weigh from 3 to 4½ pounds each. All vegetables and fruits of the temperate zone grow here in the utmost luxuriance.

Recent irrigation enterprises in Montana are the Fort Belknap enterprises by which, in connection with two others, 73 miles of ditches will be in part constructed. The area to be reclaimed will not be less than 20,000 acres; a ditch irrigating 5,000 acres between the South Mocassin and Judith rivers, in Fergus County, has been completed and is now in operation. The ditch is 16 feet wide on top, 12 feet on the bottom, and 30 inches deep, and between 8 and 9 miles in length. It taps Warm Springs Creek a short distance below the Horsehoe Bar ranch, and crosses a number of coulees, necessitating the construction of wooden fluming, which, at a distance, resembles a narrow-gauge railroad.

In the Smith River Valley a considerable storage reservoir has been created by the damming up of Lake Creek by private parties, who have secured thereby water sufficient for the irrigation of several thousand acres. These enterprises are referred to because they are typical of a large number in progress over the arid region, details of which have not been obtained, but of which enough is known to warrant the conviction that apart from the larger corporation progress, the progress of reclamation works is now as rapid as desirable.

The promise of Montana as an irrigable region is of the greatest significance and value. The estimate presented by its Society of Civil Engineers of 20,000,000 reclaimable acres is under rather than over the mark. A great deal has got to be learned as to the area of service and the economy of use in the waters that will make the lands fertile. Its two leading industries, mining and stock raising, have sometimes been esteemed as indifferent to the growth of farming and the advantages of irrigation. All this is rapidly changing and great progress may be looked for in Montana.

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers received to circulars sent by this office:

CASCADE COUNTY.

Great Falls (post-office), Robbins and McFarland (October, 1891):

Average cost per acre in vicinity for preparing land for cultivation under irrigation, $7.
Average cost per acre of irrigation works, ditches, etc., $4.
Average cost per acre for annual maintenance and repairs, 25 cents.
Products: Wheat, oats, potatoes, and hay.
Average yield per acre: Wheat, 30 bushels; oats, 50 bushels; potatoes, 200 bushels; hay, 1 ton.

Great Falls (post-office), N. T. Porter (September, 1891):

Cascade Land Company: Water supply, Teton River; area under ditch, 20,000 acres.
Irrigation works: About 50 miles ditch, 16 feet wide on bottom; 1 reservoir; dam 500 feet long, 20 feet high; 3 head-gates.
Cost per mile of ditch, about $2,000.
Cost of works per acre, $10.
Cost per acre for preparation of land for cultivation (under irrigation), about $10.
Cost per acre for annual maintenance and repairs, 75 cents.
Cost of water supply to user per acre, $10 (no annual rental of water by this company).
Principal products: Hay mostly; oats, potatoes, barley, wheat.

CHOTEAU COUNTY.

Chinook (post-office), T. C. Burns (September, 1891):

Water supply: Milk River ditch: Capacity, 30,000 miner's inches; main ditch 3 miles long, 14 feet deep at upper end, 24 feet wide at bottom, 36 feet at top, gradually becoming shallower until reaching the end of 3 miles, where it is 4 feet deep, 28 feet on top, with the same width on bottom (24 feet); at this point water is divided into two branch ditches, each 16 feet wide, 3 feet deep (2 feet below surface and banks above); length 4 and 5 miles; no reservoirs or dams; 1 head gate 24 feet wide, 50 feet long, 8 feet deep, planked and covered.
Cost of main ditch, $14,000; 16-foot branches, about $550 per mile.
Average cost of preparing land for cultivation (under irrigation), $4.50 per acre (for breaking land, harrowing, and rolling).
Average cost of ditches in grain fields, from 6 to 10 cents per rod.
Cost for maintenance and repairs, small.
Cost of water supply to user per acre, 75 cents.
Area under ditch, 32 sections; under cultivation, 800 acres grain, 3,000 acres in hay; (will be much greater next year. This year is first time water was used).
Products and yield per acre: Oats, 80 bushels; wheat, 50 bushels; barley, 46 to 55 bushels; potatoes, 250 to 450 bushels; wild hay, after first year, 1 to 2 tons; garden stuff and vegetables, etc. From 2,000 to 2,500 tons of hay cut in this valley on irrigated land; no other kind cut.

[Mr. Burns irrigated the past season 550 acres; eleven of his neighbors irrigated from 800 to 900 acres of hay land. No hay was cut except from irrigated land. The seed oats used by Mr. Burns and his neighbors was grown either in Dakota, Minnesota, or Iowa, and weighs 24 to 30 pounds to the bushel. Oats raised from that seed, under irrigation, averages 39 to 42 pounds per bushel. Mr. Burns has completed two ditches 4½ and 5½ miles long, respectively, and intends to extend the 4½-mile one across the north fork of Milk River (in a flume 120 feet long) to the valley lands, 2 by 7 miles in extent.]

DEER LODGE COUNTY.

Phillipsburg (post-office), Frank D. Brown (September 19, 1891):

Flint Creek Valley (about 30 miles long, 2 to 4 miles wide). Main water supply, Flint Creek, a tributary of Deer Lodge River.
Area under ditch, 14,000 acres.
Area under cultivation, 7,000 acres.
Irrigation works: Open ditches, each ditch owned by one ranch, generally from 1 to 4 miles, 26 by 35 feet; no reservoirs or other works.

Cost per mile of ditch, about $55 for size above indicated.

Average cost per acre for preparing land for cultivation under irrigation about $5 (includes land tilled and crops in); no preparation needed for grazing; natural grasses depended on.

Average cost per acre of irrigation works, ditches, etc., not exceeding $5.

Average cost per acre for annual maintenance and repairs, about 25 cents.

Products: Hay; also oats and wheat, used generally for fodder; yield from 1 to 2½ tons per acre.

GALLATIN COUNTY.

Bozeman (post-office), Charles A. Gregory (December, 1891):

West Gallatin Irrigation Company: Water supply, West Gallatin River (west side).

Irrigation works: Twenty-four miles canal (built over a rough and hilly country, over gulches and along sidehills, much of it in gravel and rock); first 1,300 feet is 24 feet on bottom, thence to the twenty-third mile is narrowed to 14 feet on bottom, the narrowest point at 23½ miles from head is 14 feet on bottom, grade $\frac{6}{100}$ to 100 feet or 3 feet to a mile, except first 1,300 feet which has a fall of 2½ feet in the 1,300 feet, or over 10 feet per mile; slopes, 1 to 1, except in solid rock, which is ¼ to 1; banks, 5 to 8 feet high above bottom of canal and are 25 to 45 wide at base; head gate, 24 feet wide, with 5 gates 10 by 12 and 8 by 12 (timbers); bottom of head gate 4 feet below water surface at low water; flumes, 2,722 feet, built of square timbers and 2-inch plank; flumes from 42 to 1,200 feet long, with waste gates; tunnel, 241 feet long, 5 by 12 feet, with fall $\frac{60}{100}$ to 100 feet, timbered at each end, but mostly solid rock.

Capacity of canal: Will now carry 4 feet water or 10,695 miner's inches of water.

Cost of canal, so far, $90,000; system still owns about 25,000 acres of land.

Area under ditch: The lands covered by this canal are mainly new and unbroken; there lie under it (as it may be extended by works in progress) 60,000 acres, being more than the canal has capacity to serve with water.

Area under cultivation in valley, about 50,000 acres.

Cost of water, $2 per statutory inch per year (Montana statutes).

Products: Wheat, oats, barley, timothy hay, wild hay, fruits, and vegetables.

Estimated value of products (prices paid in 1890): Average oats, $1.50 per 100 pounds; average barley, $1.15 per 100 pounds; soft wheat, 75 cents per bushel; hard wheat, 85 cents per bushel; No. 1 timothy hay, about $14 per ton; wild hay, $2 or $2.50 less than timothy (oats sometimes as high as $2 or $2.10; barley to $1.55 per 100 pounds; hay from $14 to $20).

[Mr. Gregory also mentions two other large canals in the county, the West Gallatin, 20 miles long, supply taken out of east side of West Gallatin River, capacity 8,000 inches, inexpensive head gate and wing-sieve dam, cost $60,000, built three years ago, total capacity of canal required for the land under it which is mostly all under cultivation; and the Excelsior canal, 12 miles long: cost $40,000, built by farmers and land owners under it, supplies only stockholders; carries about 8,000 inches, all supply required by lands now cultivated under it. There are innumerable farm and other small ditches—hundreds of miles of them—taken out of the many streams flowing from the mountains which surround Gallatin valley.]

MADISON COUNTY.

Virginia City (post-office); Henry Elling (September, 1891):

Average cost per acre in his vicinity for preparing land for cultivation under irrigation, from $5 to $20.

Average cost per acre of irrigation works: Ditches, etc., from $2 to $10.

Average cost per acre for annual maintenance and repairs, 50 cents to $4.

Staple products of region under irrigation: Wheat, oats, barley, potatoes, and hay.

Average yield per acre: Wheat, 30 bushels; oats, 40 bushels; hay, from 1 to 5 tons.

MEAGHER COUNTY.

White Sulphur Springs (post-office); W. H. Sutherlin (September 19, 1891):

Has 320 acres under cultivation by irrigation: Water supply, Smith River (mountain spring-fed stream); all ditches in neighborhood owned by land owners; generally open ditches, with lumber flumes where needed across deep ravines; no reservoirs.

Cost of ditches, etc., per mile, from $120 to $300 (his own ditch cost $240 per mile); cost per acre, about 40 cents.

Average cost per acre for annual maintenance and repairs, 12½ cents.
Cost of water supply to user per acre, $8.60.
Area under ditch (in Smith River Valley), 11,000 acres (above the cañon).
Products under irrigation: Wheat, oats, barley, alfalfa, timothy, blue joint, clover, potatoes, beets, turnips, cabbage, and most varieties of vegetables.
Average annual yield per acre: Wheat, 42 bushels; oats, 51 bushels; potatoes, 320 bushels.

MISSOULA COUNTY.

Cañon Ditch Company (to be completed May 1, 1892):

Ditch to be taken out "a mile above foot of Blackfoot River; contract calls for ditch 13½ feet wide on top, 6½ feet at bottom, 3½ feet deep, 7½ miles long; cost, $30,000; to irrigate all South Missoula."

PARK COUNTY.

Livingston (post-office); George J. Allen (September, 1891):

Water supply: A mountain stream carrying from 500 to 700 inches of water.
Irrigation works: 12 miles of ditch ("about 6 miles through an old channel ditch 6 feet wide, 2 feet deep"), one main headgate and one for each ranch served.
Cost of works: First cost, $200.
Cost per acre of ditches, etc.: "Near mountain stream from 10 to 25 cents, but ditch taken out of a river, $5 to $10."
Cost for annual maintenance and repairs: Twenty-five dollars per year will cover all expense under this ditch.
Area served by ditch: Nine hundred and sixty acres.
Area under cultivation: The whole 960 acres plowed and in grass.
Products in neighborhood and yield per acre: Wheat, 15 to 50 bushels; oats, 30 to 90 bushels; barley, 15 to 50 bushels; potatoes, 100 to 500 bushels; fruits and vegetables.

CENSUS FIGURES FOR STATE.

The United States Census Office (Bulletin 153) reports for this State (Mr. F. H. Newell) as follows for the enumeration year 1889-'90:

Number of counties	16
Number of irrigators	3,706
Total acreage irrigated, and in crops	350,582
Average size of each farm in acres	95

NEW MEXICO.

Quoting the words of the monograph on New Mexico, which forms part of a report by the United States Signal Service, on "climatology, irrigation, and water storage in the arid region," it is to be said that the logical sequence of such inquiry can be summed up, as showing that—"Agriculture depends on irrigation, irrigation depends on the rivers, the rivers depend on the clouds whose attenuated humidity is made to appear as rain and snow by the influences largely controlled by the altitude and configuration of the mountains." The determining causes then, are to be found "in geographical physics." The mountains both supply and direct the rivers. In New Mexico the Rockies lose their continental individuality, and southward from Pikes Peak, but chiefly within the land of "Poco Tiempo," this great range becomes a series of semi-detached masses and sinks into rolling formations, spreading out as sloping mesa or table-land, though still of high altitude. Below Marshall Pass in Colorado, the Continental range divides—one portion entering New Mexico to the southeast, the other swings to the southwest. This portion forms a watershed between the Rio Grande and the Rio San Juan, making an important part of the basin and plateau hydrography of the Rio Colorado system. Between these divisions of the Continental range is the superb basin valley or dessicated lake bed known as the San Luis Park. From the western portion thereof rises the Rio Grande Bravo del Norte and through which it flows, making almost a direct course east and west by a little north and south, until it turns directly southward, forcing its way through the Raton range, a part of eastern limb of the Rockies. This section preserves more fully the characteristics of the great range and it is locally known as the Sangre del Cristo, Taos, Raton, and Santa Fe ranges. The Raton, which is the extreme eastern section, forms a plateau or table-land with a general elevation from 7,000 to 4,000 feet. At the latter altitude it descends 1,000 feet or more and almost precipitously into the valley of the Upper Pecos, which flows through and divides the eastern portion of New Mexico. As a water storer the Raton range, fed also from the higher altitudes of Taos and Sangre del Cristo, is destined to play an important part in the reclamation of an area of great extent, fine climate, fine possibilities for agriculture, and of striking topography and picturesqueness. The Rio Grande Basin, below the San Luis Valley, is dominated on its east side by the Taos and Santa Fe ranges, rapidly breaking away into the detached elevations and mesa known as the Oscuro, Sierra San Andreas, Organ, and Sacramento mountains. On the western side the formations take the name of Datil, San Francisco, and Mogollon ranges, till reaching and passing the Upper Gila they fade away into the Sierra Madres in Old Mexico, forming the Chiricahua Mountains in southeast Arizona.

New Mexico, as a whole, can be regarded as a broken plain of 5,000 feet elevation, controlled by two systems of higher altitude, marked by several smaller ranges on its eastern and southern faces, with one large

Rio Pecos near Roswell, New Mexico.

bisecting river channel cut through its center from north to south, and having another marking in a similar manner about two-thirds of its eastern half. The result of this mountain topography is to divide the region as by walls, separating it into different areas or chambers, each having different relations to hydrology and climate. Three-fourths of New Mexico then has an average elevation of 5,000 feet. In the southern portion it is less, generally 4,000 feet, and at three points in the Rio Grande up to Fort Thorn, along the Canadian to Fort Bascom, and the Pecos Valley up to Roswell and above, the altitude runs down to 3,000, and in the last-named area to about 2,000 feet above sea level. Two range systems rise from the general level to the height of over 7,000 feet each. They are grouped, says Lieut. Glassford, "like a wall against the western boundary or form a dependent projection on the northern line, thus accentuating the southeastern facing of the system. From this general mountain altitude many summits rise 2,000 feet or more and there are peaks which lift their precipitous slopes and bald, deeply scored faces, to an altitude of from 10,000 to 12,000 feet. Their climatic purpose is to extract moisture from the atmosphere for the benefit of the lower levels; they do more than this, for the rain carries away the disintegrating rock to enrich the plateau and the valley beneath." So far then as climatic influences are concerned, these topographic statements show that "for the rest the country is mesa of even surface despite its great elevation; it is nearly level table-land, whose depressions and elevations are but slight, presenting to the lower plateau a characteristically bluff face. Such a surface, looking to leeward, can oppose but little resistance to the moisture-bearing wind as it passes over it; it must pass the wind and its freight along to condense upon the mountains. Arizona faces the prevailing humid wind and opposes to it a flight of steps; New Mexico is almost entirely on the leeward side of the mountain ranges and exposes a minimum of bluff surface to the wind. Hence arise different climatic conditions, and their study is thus," says Mr. Glassford, "intermingled with the correlation of the mountain systems."

The several drainage basins are marked by the great divides which characterize the peculiar parietal formations of New Mexico. The Continental Range is first and forms the southwest watershed between the two oceans. It enters the Territory in Rio Arriba County and passes into Mexico along the Sierra de las Animas. It contains two large basins, the San Juan and the Gila, and the small one made by the Zuñi drainage. There are ten peaks within its borders, ranging in elevation from the Animas, at 6,105 feet, to the Jamez, at 11,260 feet. The second divide approaches the meridian at middle of the territory. Its northern ridge is found along the Sangre del Cristo Range, until it finally sinks in the high mesa below Santa Fé. It then forms a high plateau across the Gallinas to the Sierra Blanca, and disappears in Texas by way of the Sacramento Range. It contains eight outlying peaks, ranging in altitude from the Franklin, at 6,890, to the Tucha, at 13,150 feet. The western shed may be related as the Pacific and the eastern as the Atlantic divide. Geologically speaking, there are within the area, four distinctly marked epochs. They are the Archean, entering from Colorado; then follows the palæozoic and mesozoic periods. The cretaceous covers most of the lower surface and outlying areas. "There occurred four distinctly marked upheavals of eruptive rock at wide intervals. As conditioned by these general characteristics the rivers of the Territory are few." The river systems of New Mexico, then, are the San Juan to the northwest, the Gila to the southwest; the Rio Grande through the central basin from north to south, the Canadian in the north from northwest to southeast, and the Pecos from north to south in the section lying east of the mountain ranges that easterly border the Rio Grande. In this division there is to the east a subdiversion, marked about the latitude of Las Vegas. East and north of this line "the waters drain through the Canadian, the Cimarron, and the Arkansas into the Mississippi; south of the line the Pecos drains the rainfall across western Texas into the Rio Grande." Two very important systems of irrigation are found within these drainage basins. In Colfax County to the north, supplied by the headwaters of the Canadian, the owners of the Maxwell grant, with other landholders, are carrying forward an extensive system of open storage and distributing works, by which about 75,000 acres of table-land are being brought "under ditch" and some 6,000 acres of which are already under cultivation.

Besides these enterprises in the mountain table-land and under the waters of the Canadian there are a number of local irrigations in progress for orchards and farms in Colfax and Mora counties. Some of these are of value to the student as illustrating the altitudes at which fine fruit may be successfully grown and good grain and forage fields be sown and harvested. Mr. S. W. Dorsey, one of the largest land-owners and ranchmen whose home residence, Chino Springs, Colfax County, with an altitude of over 8,000 feet, has its fruit trees, berries, and vegetable garden supplied by water through a half-inch pipe from a little but constant phreatic flow obtained by an opening made in the side of a bluff at the back of the dwelling and out-buildings, is engaged in constructing reservoirs on the table-land for the purpose of storing local rainfall and storm waters. In the counties of Lincoln, Chaves, and Eddy (also San Miguel), formed out of the Pecos basins, there are two extensive systems of water storage, distribution, and cultivation by means of irrigation now in progress. One of these, in Eddy and Chaves counties, has irrigation works constructed to irrigate nearly 300,000 acres. Artesian waters have also been obtained at Roswell, and large promises of an important supply are found in several directions. The southwest basin or the Upper Gila is small and not more than 50 miles in width. Like that of the San Juan Basin in the northwest, it belongs climatologically to the Pacific group. There is a growing activity in the San Juan Basin. From there directly southward the areas of possible reclamation or present cultivation are small. There will be an increase in this direction of small areas at favorable points as farmers and settlers comprehend more clearly the conditions under which a drainage supply may be tapped, dug out, bored for, and recovered for use in cultivation. In the Upper Gila Basin the rainfall is commonly sufficient to make a success of the ranchers' rude but profitable "dry" farming.

> This drainage basin is therefore removed from the discussion of irrigation as influenced by climate, but its bounding ranges remain as one of the important and far-reaching factors of the climatic problem of the Territory. (P. 320, Signal Service Report.)

The central basin, that of the Rio Grande, forms not only the principal pathway north and south, but it is also the chief seat of population at present. Its waters are mainly from the snows of the Continental Divide within the borders of Colorado, though replenished by the local precipitation of its subsidiary basins. The tributaries are numerous in its upper course, but after leaving the Taos Cañon they become less frequent; in fact it has, below the point at which the Santa Fé and Galisteo pour in their torrential flow, no confluents of any magnitude. The oldest irrigations within the United States are to be found within this valley, unless exception be made of the phreatic cultivation, whose evidences are to be traced in connection with the ruined Pueblo towns of the Rio Chella, etc., and in the Salt River Valley, Arizona. The 18 Indian pueblos now existing in New Mexico are sustained as to cultivation by the Rio Grande's hydrological conditions, and they long antedate the present Mexican farmers. The oldest of the latter settlements is undoubtedly that in the Mesilla Valley, the rich soil of which has been in constant cultivation under irrigation by them the past three centuries. Portions of the Santa Fé Valley above settlements at Albuquerque and in San Bernalillo counties are next in order, and later still are the farming communities of Conejos and Costilla counties in Colorado.

The hyetophysics of New Mexico will be more readily comprehended after this summary of its topographic conditions. Lieut. Glassford says:

> The Pacific Ocean is the reservoir of Arizona. Its evaporated waters are carried by the prevalent southwest winds over plateau systems which gradually increase in altitude and every such step opposes its maximum condensing surface to the characteristic wind. The culmination is reached in the system of lofty ranges which overtop the highest plateau. From this local action of condensation differentiating the circulatory inspiration of continental lows which move east of the Rocky Mountains there arise two systems of precipitation which present a noteworthy difference in character. The winter rains are diffuse as regards the area of territory affected; they are moderate in force; they are interrupted by the anticyclonic types of high barometer and cloudless skies, which are distinctive of the Pacific coast weather; they are in unmistakable correlation with the systematic climate of the country. The summer rains are different; in extent they are concentrated; they are uniformly local and attributable to local influences; they are characteristically of great violence, which often seems to justify the mistaken appellation of cloud-bursts. One other point needs to be held in mind, and that is that the records show in reality only the minimum fall of rain, since observers' stations are mainly in the valleys where their gauges make no record of heavy rains which are in sight upon the surrounding mountains.
>
> That the rainfall of New Mexico is but a continuation of the Arizona system, a projection of Pacific humidity across a congeries of condensing mountain bodies the ratio of whose efficiency is geometrical, will appear from a study of the phenomena here presented. For convenience in support of this proposition the records of rainfall will be presented under the two titles of winter and summer rains, which the period of their occurrence most naturally suggests, a distinction which, provisionally assumed for convenience, will be found clearly proved step by step as the argument proceeds. (Irrigation and Water Supply in the Arid Regions, p. 321.)

The winter rains in New Mexico are to a considerable extent of the Pacific type, though they are to more or less extent obscured by their long inland movement. Their tendency is to diffusion; hence a certain loss. The climatic conditions of the Rocky Mountains affect them seriously, especially as to "the march of extensive areas of low barometer," which are deflected to the north by the impact of the range, and thereby cause their movement toward the Atlantic. They differ also from the Arizona season in being divided "by longer and shorter periods of high barometer." The winter precipitation is expected by December in Arizona. In New Mexico it does not begin as a rule till the earlier days of January. The basins directly under Pacific influences are in line with the isohyetal or rain curves of Arizona. In January the general average of the Territory conforms to the law already indicated, and in February, when these seasonal curves begin to break "down into scattered local areas," the conditions have become markedly strong in New Mexico. By April the winter rains are definitely ended. But in the eastern or Atlantic divide section, an area of considerable precipitation remains. This follows the high summits of the Sangre del Cristo until it sinks into the table-land or mesa of 4,000 feet, thence it tends southeasterly across the Pecos head-waters region as far as Gallinas Spring, whence it sharply curves to the north and extends over the Raton Range. The winter rains in the nomenclature of the meteorologist are marked by isohyetal curves of from 7 inches to 1 inch of precipitation. These curves are outside the mountain lines. The 5-inch curve is associated with the Arizona rains, and, with that of 4 inch, belongs to the Gila Basin and the head waters of the Colorado Chiquito. A curve as high as 17 inches appears on the mountains of this area. The 6 and 7 inch curves are found about the high levels of the Sierra Blanca, and the 5-inch curve related to them runs northward along the westward wall of the Pecos Valley as far as Colorado, just west of the upper Canadian. A curve of 2 inches is drawn across the plains of the Mimbres as far east as the Mesilla Valley, and thence it deflects southeasterly into the Pecos. The 3-inch follows the Mimbres lines until it reaches the Rio Grande Valley. It is then drawn sharply northwards to Socorro, where it expands to include Laguna and Albuquerque, whence it again deflects southwards until it reaches the Organ Mountains. These curves indicate the diffusive and diverting influence of the topography on the aqueous currents borne to New Mexico from the South Pacific Ocean across Arizona.

The summer rains are otherwise influenced, for the highest or 11-inch curve appears upon the levels west of the Canadian River and on the cañon course of the Pecos. In some parts of its progress the curve reaches the 15 inch, which includes Las Vegas and Fort Union. Two segments south of these points draw close together at Luna and then expand further to the south, reaching the 14-inch curve at Fort Stanton. The lower summer curves are found in the sections most favorably affected by the winter rains. The minimum curve of 4 inches is found in the southwest. An adjacent one of 5 to 6 inch crosses the Gila Valley, skirting the Mimbres plains (Deming and northward) and passes out into the lower Rio Grande Valley. There are high curves of from 8 to 15 inches along the Continental Divide summits. The seasonal precipitation drawn in from Arizona along the San Francisco Valley gains a systematic curve of 7 inches, running over the mountains until it reaches the Rio Grande at Fort Seldon, and thereby favorably affects the Mesilla Valley. It is then drawn northward along the western wall as far as Embuda, and thence deflects southward, finally passing into Texas.

These statements illustrate the radical distinction in type of the winter and summer rains. The author of the New Mexico monograph utilized here says: In winter that humid winds are drawn "across the region under discussion by the influence of low areas over regions near or remote. In the summer the winds rush from all sides towards the heated mountain masses, and the precipitation resulting therefrom is distinctly local" (p. 324). In winter, what are termed "the continental lows" hang long upon the Rockies or are swept eastward "with varying velocity." This type "is a simple one and well characteristic climatic group." It is thus described:

> Step by step the humid winds are drawn over graduated plateaus and extrusive summits, and at each higher step discharge so much of their moisture as is a surplusage over the saturation amount of atmosphere of a given tenuity at a given temperature. There is nothing violent in these systematic drafts of humid air from the sea toward the continental cyclones; the air is chilled by the seasonal causes which make the winter climate; the earth surfaces soon become largely covered with snow and their radiating influence is thus mechanically obliterated; the air lies in practically

> even strata of uniform temperature. The humid wind is drawn along these ruling conditions; on every plateau it discharges down to the point of saturation; the diminution in absolute amount of moisture is constant and large; by the time it overlies the Rio Grande trough its last available moisture has been condensed by the heights of the Continental Divide and sifts down to the leeward. Practically desiccated the current reaches the summits of the eastern or Atlantic divide; it has but little rain to deposit for the immediate agricultural benefit of the plains; such precipitation as is induced appears as snow which forms a storage reservoir whose supply is constantly utilized until July. Therefore are the winter rains confined in the main to the western member (p. 324).

The summer winds or "temporales" are from atmospheric strata, drawn from the sea over land surfaces, under the influences "of mechanically directing guide planes," at sea level and mean temperature "calm air is in a position to take up and hold in suspension moisture up to the point of saturation." As a result of change of higher position and of temperature, the point of saturation is also changed; there is more moisture than the aërial gases can hold and precipitation follows. Another factor is that of radiation. If topographical surfaces are heated by the suns rays, the aqueous currents as they rise and pass are immediately affected. This factor is the dominant one in relation to the "temporales." Lieut. Glassford says:

> When the elevating plane over which the air is drawn is covered with snow, this factor is in its lowest terms. Snow reflects the incident solar heat back to the air through which it has just been transmitted, and as the air is highly diathermanous it is very little affected by this original and reflex passage of heat, which furthermore is near its minimum during the season when precipitation takes the form of snow. Though an excellent reflector of heat, snow is also a notably poor radiator, and forms a screen which prevents in a large measure the diffusion of the heat which the mountain mass has collected by absorption and stored during a warmer season. It therefore appears that the temperature of the surface of a snow-clad surface of elevation differs but little from the absolute temperature of air normal at the same elevation. Over a region governed by such an elevation it is most likely that the superterranean planes of temperature and saturation are evenly distributed. In such case the induced air body raised by the guide plane of the mountain slope into successive planes will move continuously and with the least disturbance, and will lose of its humidity only such a minimum amount as will suffice to reduce it to the saturation point of each successive plane, and thus will carry its maximum to be precipitated on distant regions in its appointed course.
>
> With the vanishing of this screen of snow the conditions proportionally alter. The surface of elevation, with its soil and rock masses, ceases to reflect the incident heat ray of the sun, but absorbs much of it. At the same time it radiates the heat which it receives, currents are formed in the surrounding air, and the mountain becomes a focus of activity, about which are currents rushing rapidly skyward and a lateral indraft to supply the place of the air withdrawn by this action of convection. The air passing the snow-clad mountain is raised to the minimum elevation which will enable it to pass beyond; its precipitation is the minimum, its reserve is available for higher ranges. The air, influenced by the radiating mountain mass, is forced to the highest elevation which the upward current can reach, as is shown by its frequent precipitation as hail; it is subjected to the greatest change of pressure and temperature; its excess moisture and consequent precipitation reaches the maximum; it is almost desiccated, and on even higher ranges beyond can cause no precipitation. All these theoretical features are observed in the New Mexican rains (pp. 24, 25).

From June to September the effects of this phenomenon may be seen practically illustrated. In June the ranges are still snow clad, though vanishing. There is the minimum of discharge as a result, with vague diffusion over large areas. In July the snow is swiftly disappearing, and humidity is restored to the air, while the rain becomes general to the leeward of the mountain. There is but little difference in precipitation for August. In the western field the humidity is passed "rapidly to very high altitudes and makes a high precipitation upon the immediate region." In other words, in that portion which belongs to the Pacific climatic influences, the summer rains are adaptable for storage use, and not for immediate terrane distribution. The eastern section, or Atlantic divide, on the other hand becomes a focal ridge of "great radiation and intense activity of convection." The largest precipitation then is in the two months of July and August. In September the "temporales" disappear, for the

> two mountain masses are fully developed as ridges of radiation and convection, the available humidity has been almost exhausted, and although the condensation takes place at high altitudes yet the general air temperature is so much elevated that the practical effect of height on temperature is considerably lessened. The rainfall is materially less; it appears as indefinite areas of slight intensity, and thus the temporales disappear (p. 326).

Evaporation observations, Mr. Glassford says, authorizes the drawing of provisional curves over portions of New Mexico, of from 70 to 90 inches of annual loss. The lowest curve corresponds with the Sangre de Cristo and Pecos-Canadian section; that is the north end portion. The 80-inch curve sweeps in across the southeast portion, where it sharply recurves and goes westward to the Gila Basin. The highest curve affects the whole of the southern section of the Territory. According to the weather-service paper, New Mexico formations are directly related to phreatic supplies. The writer quoted accepts the term "underflow" first used by Mr. J. W. Gregory, of Kansas, and since brought into special use by this office during the "Artesian and Underflow Investigation" as the one best adapted to express the nature of the subterrane or drainage water supplies which were reasonably conjectured as existing when our inquiries began, and for the use of which ample proof has already been obtained. With Mr. Glassford this office agrees that it—

> Must be rigidly stated and strictly understood that in the present state of knowledge no competent evidence exists to prove that this underground water supply partakes in any sort of the nature of a stream sufficiently to authorize the use of the word flow. In individual instances a flow may be proved in continuation of the above-ground flow of the lost rivers characteristic of the region, but that the general body of underground water has any such progression is certainly not proven.

No general claim for sub-flow has ever been made. Only in assured cases, subject to demonstration, would it be allowable. But that all phreatic waters have a propulsive or directive movement, however slow, is in my judgment a demonstrated fact. The evidence is ample and extends over many years and different lands. The existence then of phreatic waters in New Mexico is already established. In the annual report on Internal Commerce, for 1888, published for the Bureau of Statistics, U. S. Treasury, there is among others a valuable paper on this Territory giving by towns and villages the location and character of earth waters utilized as springs, wells, etc., for town and farm purposes. The number is surprisingly large. Artesian water has already been reached a few miles below Springer, where the Raton tableland begins to decend into the upper Pecos wall, and at Roswell, in the lower Pecos Valley, where a number of flowing wells are now in operation. At Eddy two wells are being drilled with good prospects of success. This is a region of heavy springs, and to the eastward of the Pecos rising water is obtainable in all directions and at moderate depths by dug wells. At Deming and the neighborhood nearly 100 such wells are in operation. The lifting power employed is that of the windmill. On the Journado del Muerto several tubular wells are a moderate success. South of Galisteo Creek, on the Florida plains, and in Manzano Valley, as well as in the Pecos Velley, such waters have been found. The extensive intra-mountain plain or valley, lying to the east of the Organs and between that range and the Guadalupe, is without a single surface stream or spring. Yet there is little doubt that it is extensively supplied with underflow or phreatic waters, and there is reason to believe, as the existence of old ruins in the upper portion shows, that it must once have been watered by flowing streams, having large portions subjected to irrigation by the same prehistoric race that have left their industrial evidences elsewhere in the southwest. As these underflow waters are obtained, the question of power becomes one of importance. Mr. Glassford recommends the utilization of the wind by means of mills and gives the following table (page 327):

Hourly wind movement.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Santa Fe	7.1	7.2	6.9	8.0	7.6	6.5	6.0	5.4	5.1	5.9	6.2	5.8
El Paso	4.9	5.6	5.8	6.6	6.3	5.7	4.7	4.8	4.5	4.3	4.5	4.8

IRRIGATION COMPANIES.

According to the latest report of the governor, the following have been incorporated since September 1, 1890:

The Pope Land and Irrigation Company. Locality: East side of Pecos River, in Eddy County and Texas.
Apache Valley Irrigation Company. Locality: Apache Valley, Colfax County.
The San Mateo Irrigation Company. Locality: San Mateo River.
The Rio Grande Land and Irrigation Company. Locality: East side of Rio Grande, in Sierra and Donna Ana counties.
The Sacramento Irrigation Company. Locality: Sacramento River.
Mimbres and Deming Ditch and Pipe Line Company. Locality: Mimbres River, Grant County.
The Puerto de Luna Ditch and Colonization Company. Locality: Pecos River, San Miguel County.
Bosque Redondo Irrigation Company. Locality: Pecos River, San Miguel and Chaves counties.
Rio Grande Interstate Land and Improvement Company. Locality: East side Rio Grande, from 200 yards below Earlham Bridge to south boundary of Refugio Grant, about 18 miles.
The Felix Land and Water Company. Locality: Rio Felix, Lincoln and Chaves counties.
The Mimbres and Deming Canal Company. Locality: Mimbres River, Grant County.
The Tijeras Water Company. Locality: Tijaers Cañon, Bernalillo County.
The La Plata Ditch Company. Locality: La Plata River, San Juan County.
The Santa Fe Irrigation Company. Locality: South side Rio Santa Fe, Santa Fe County.

IRRIGATION PROGRESS.

The future of the Territory of New Mexico largely depends upon the increase of its cultivated area through irrigation. The great systems now in process of construction and enlargement on the Pecos, Nimbres, and the Maxwell grant, illustrate the rapidity with which the art is progressing. These systems are elsewhere described.

In San Juan County, according to Mr. J. G. Kello, there are approximately 200 miles of main ditches, covering about 24,000 acres of land. About 175 miles of these are owned and operated by the farmers themselves, and are partnership ditches and not incorporated. This length of ditches is all under operation. There are also from 40 to 50 miles of uncompleted ditches. It is estimated that it requires at least one cubic second foot to irrigate 160 acres of land in San Juan County. The average cost of water throughout this county is about 75 cents per acre.

In Santa Fé County during the past year, 1891, irrigation activity has been very marked, and as a result 600,000 pounds of apples and

300,000 pounds of other fruits, raised by irrigation, were shipped from Santa Fé.

Mr. Arthur Boyle, one of the best horticulturists in that locality, furnished the following information: His orchard of 6 acres was planted in 1886, and bore its first full crop in 1888. Apples, peaches, and nectarines flourished; raspberries, with the exception of the cuspid, stand the winter cold without protection; other berries mature earlier than in the neighboring States and Territories, and enjoy a noncompetitive market for about three weeks. Land, with water, fit for fruit near Santa Fé is worth $100 to $150 per acre. The same land well planted will command $1,500 per acre and upward. In 1888 Mr. Boyle made an experimental shipment of peaches from Santa Fé to a merchant in Denver, with whom he was unacquainted, and received a telegraphic order for all he could send. This was because the fruit was not only of a high grade but was on the market three weeks before the California crop. Last year he sold $2,700 worth of fruit from his 6 acres.

The style of irrigation is the old Mexican acequia, and there are about 700 users of water in Santa Fé. Under the law no man can vote for mayor domo acequia unless he is an actual irrigator. The poll books of precincts Nos. 3 and 4 show that over 300 persons voted at the last election in 1890. In the following precincts the people depend entirely upon irrigation for a livelihood: Santa Cruz, Espanola, Chimayo, Nambe, Pojoaque, San Ildefonso, Tesuque, Upper and Lower Santa Fé, Agua Fria, Bajada, and Galiesteo. These will average 55 votes in each precinct, or about 660 irrigators. There are 17 irrigation precincts in Santa Fé, and nine-tenths of the irrigation is carried on by the native resident New Mexicans.

Wheat yields 30 to 40 bushels to the acre, at a general average of 75 cents per bushel. The cost of production would be about 15 per cent of the gross value. Alfalfa averages 2½ tons to the acre, and for the last three years has sold for $95 per acre, gross. It costs about 10 per cent to cultivate. Fruit will yield an average of profit of $250 to $1,500 per acre. As high as $800 worth of apples alone have been sold from 1 acre near Santa Fe.

The number of acres under cultivation in Santa Fé County is not large, owing to the scarcity of water and rainfall. The possibilities of redeeming large tracts by the construction of reservoirs and ditches are, however, shown to be great, as reported to this office by Mr. Hartman, C. E. The sections now under cultivation by irrigation are in the Rio Grande Valley or along the bottoms of creeks; but as the latter sink on reaching the lowlands, or as soon as they reach the cretaceous formations, an immense amount of water is allowed to run to waste during the spring by the absence of suitable provisions for its storage. The soil is excellent, and produces large crops of the best quality when irrigated. Valleys and cañons in the mountains or close to their base have a heavy silt. All of the streams in the county emanate from the Santa Fé range, flowing westward into the Rio Grande. These water courses, from north to south, are the Canada Chimayo, Nambe, Tesugue, Santa Fé Creek, heading at Baldy and Lake Peaks, respectively, and Galisteo Creek, rising with its two heads, Apache and Canoncito creeks, near the summit of the southern end of the Santa Fé range. Their waters are derived from snow, rain, and springs of the mountains, in Archæn rocks, flowing hence through carboniferous beds, finally reaching the cretaceous formations (Santa Fé marls) which fill the valley between the mountain range and the Rio Grande, superlaid nearer the latter by sheets of basalt thrown out from the Tetilla.

Irrigated Market Garden in Santa Fe, New Mexico.

Santa Fé County has an area of about 2,159 square miles, or 1,381,760 acres, of which 603,040 acres are covered by Mexican grants. Of these about $\frac{8}{50}$ per cent are strictly agricultural, *i. e.*, irrigated, used without irrigation, or are easily put under ditch. They may be classified as follows:

	Acres.	Irrigated.	Irrigable.
1. In Rio Grande Valley	13,120	4,500	8,620
2. In Chimayo Valley	1,280	640	640
3. In Nambe Creek Valley	2,880	800	2,080
4. In Tesuque Creek Valley	3,520	1,520	2,000
5. In Santa Fé Creek Valley:			
(*a*) From waterworks reservoir to Aqua Fria, 8 miles	8,320	5,760	2,560
(*b*) Ceeneza and Ceeneguilla	2,560	960	1,600
(*c*) Vicinity of Penos Ranch	320	120	200
6. In Galisteo Creek Valley:			
(*a*) In Apache Creek Valley	1,420	140	1,280
(*b*) In Canoncito Creek Valley	480	180	300
(*c*) On Long Grant Valley	2,400	200	2,200
(*d*) At Casa, Colo	1,920	920	1,000
(*e*) In Galisteo Creek Valley to Cerrillas	3,360	400	2,960
(*f*) In San Cristoval Arroyo Valley	2,080	800	1,280
(*g*) In El Chorra Valley	1,920	160	1,760
(*h*) In San Marcus Arroyo Valley	1,120	160	960
7. In Cañados Facundo, Ortiz, and Galleyos	1,380	680	700
Total	48,080	17,940	30,140

The 17,940 acres now under cultivation and irrigation have their water conducted to them by a system of ditches (acequias madre) and their laterals, with a length of not more than 33 miles. The general formation of the country is very favorable in its natural slopes.

The area of land which may be cultivated for the raising of crops without irrigation is 18,540 acres.

These lands are situated on the Pecos Mesa, in the vicinity of Glorieta, on the upper portions of Arroyo San Marcos, and the various openings from the mountain sides into the plains on the east and west.

Bottom lands can be made available by the construction of dam storage for reservoirs to the extent of 12,354 acres. They are on the Santa Fé Plains.

	Acres.
1. Valley of the Arroyo de los Chamisos	2,880
2. Valley of the Arroyo Hondo	3,560
3. Valley of Cañada de los Ranchos	1,600
4. Valley of Cañada de los Minos	934
5. Valley of Cañada Aocha	1,660
6. Valley of Arroyo San Marcos	1,720
Total	12,354

This is upland available by the construction of small dams to the extent of 20,840 acres. There may be located (1) on the Santa Fé Plains, surrounding an abandoned artesian well location, 5,200 acres; (2) in basin worn out by the Arroyo San Cristobal and Arroyo La Iara, south of Galisteo, 5,640; total, 10,840 acres.

Santa Fé Creek runs about 3,326,000 cubic feet of water every twenty-four hours during February, March, and April of each year, giving a sufficient quantity to irrigate 80 acres per day, or 8,000 acres in, say, one hundred days. This amount now runs to waste. The quantity of water during May and June is somewhat less, but generally sufficient to irrigate the land now under cultivation. The water of the rainy season, July and August, is also used for the same purpose. All the water of the remaining five months, September to February, which is calculated to amount to about 250,000,000 cubic feet, would, if stored, be sufficient to irrigate about 6,000 acres more; or, in other words, there is sufficient water in Santa Fé Creek to irrigate 20,000 acres if properly handled.

Nambe Creek runs about three-quarters of the quantity of Santa Fé Creek. Tesuque Creek, after the junction of its several heads, about the same as Santa Fé Creek. Galisteo Creek about one-half of Santa Fé Creek to within 2½ miles of Lamy. Arroyo of San Cristobal runs about one-third of Santa Fé Creek.

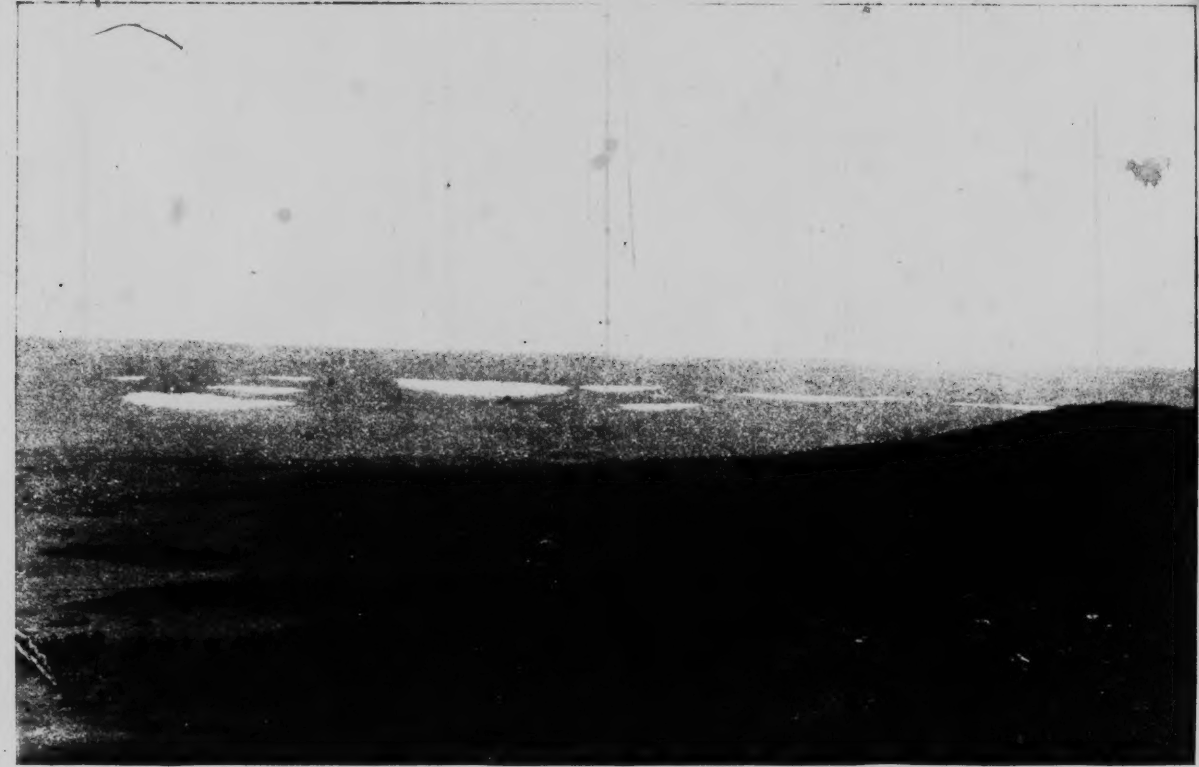
Nambe, Tesuque, and Santa Fé Creek carry their water as long as they run through archæan and carboniferous formations, and the heads of Galisteo (Apache and Canoncito Creeks) while passing over the Archæan, which is superlaid directly, at its base, by Dakota formations. All become intermittent on reaching the Cretaceous or Galisteo beds, respectively. By building dams across the creek beds at intervals of several miles all the water could be retained and made use of to irrigate large tracts of lands now lying idle. The heads of arroyos and cañadas, on the Santa Fé Plains, afford opportunities for building reservoirs. In the southwestern part of the country, where the cañadas open eastward from the mountain slopes on the west, dams for reservoirs are easily constructed. Water can be obtained in the apparently dry creek bed of the Galisteo at a depth from 15 to 20 feet.

IRRIGATION ON THE RATON TABLE-LANDS.

The table-lands of the Raton Range have several times been referred to. That portion under what is known in New Mexico as the Maxwell grant is the seat of an irrigation enterprise of a most important character. The altitude, topography, hydrography, and climatic conditions all unite in giving prominence, from both an engineering and economic standpoint, to the irrigation works, administration, and cultivation that are in progress in northeastern New Mexico. The special agent made a close personal examination of the area and hydraulic system in the early summer of 1891. Impressed with the belief that the success of the systems in operation upon the Maxwell grant would demonstrate the possibility of an arable reclamation of many million acres of high table and plateau lands, several days were given to the inquiry and over 100 miles of driving was done at an elevation between 6,400 and 8,000 feet. The conclusions reached are given in a condensed statement of the notes made at the time. There are two ditch systems under the Maxwell operations and one other under the control of Mr. Springer. The source of supply is found in the snow-fed head waters of the Canadian and Cimarron rivers and in the local precipitation of the foothills and table-lands.

The Springer Ditch (Maxwell) system contains about 22,000 acres under ditch. There is one large reservoir called Springer Lake, situated at 5 miles from Springer, with a capacity of 5,000 acre-feet of water; besides there are also several smaller lakes and one settling basin. The smaller lakes together have a storage capacity of, between them, 1,000 and 1,200 acre-feet of water. There are 55 miles of main ditches and large distributories or laterals. The water for this system is obtained from the Cimarron and Ponil rivers, and the head gate is situated at the junction of these rivers. It is not yet possible to estimate with accuracy the average flow per year of these streams, for the first gauging station was only established on the Cimarron in 1890.

The grade of the main ditch is about 5¼ feet per mile. It is 20 feet



RATON TABLE LAND RESERVOIRS.

View from Saltpeter Rock, Taos Range, Colfax County, New Mexico.

wide at the bottom and about 4 feet deep. There is no question of the water supply made being equal to all wants. If all the land were sold under the Springer system, any demand for water would have been satisfied. As to the Vermejo system, there can be irrigated at present 30,000 acres, and that, too, without further extension of the system by building additional reservoirs. The reservoirs and their capacity are as follows:

	Acre-feet.
Lake 1	200
Lake 2 (Laguna Madre)	2,100
Lake 4	300
Lake 5	1,000
Lake 7 and 8	11,000
Lake 10	200
Lake 12 (Oyster Lake)	3,000
Lake 13	1,700
Lake 15	200
Lake 16	200
Lake 20	300
Total	20,200

Besides these there are several depressions, which can be utilized by making deeper cuts and building embankments around them, if at any time the system should be increased. There are about 50 miles of main canals and main laterals of same depth and width as those of the Springer system. The Vermejo system may be extended to the north and east. Below the present head gate, about 4 miles lower down the river, an additional ditch is being built, which, tapping the Vermejo River, will receive an additional flow on account of several springs rising thereabouts, between the present head gate and the ditch now building. This is called the low-line ditch, and will cover an additional area of 7,000 acres, at a total expense of $7,000, including a rather expensive iron flume, a late invention of a Denver patentee. It is proposed, in the event of conditions warranting it, to make an addition to the system by going higher up into the cañon, with a view to the possibility of dry seasons. To increase the amount of water, it is proposed to build a storage reservoir about 15 miles above the Vermejo head gate in the mountainous part of the river; the plans are already made, the location chosen and surveyed. Owing to the amount of water now available, this project is postponed to another year. Such storage reservoir would be located at the junction of the Caliente and Vermejo rivers and would have a capacity of 5,000 acre feet; the expense of this construction may be estimated at $50,000; and the reservoir could be filled repeatedly during flood seasons every year.

It is also designed to construct a reservoir covering 3,500 acres to collect the waters from the Cieniguilla and Cimarron rivers at the head of Cimarron cañon, about 30 miles northwest of the present head gate of the Springer system. This reservoir, which has been surveyed, would irrigate 160,000 acres; the proposed dam would be 140 feet high, 100 feet long on the bottom, and 275 feet on top. It will contain 312,000 cubic yards of material. It would irrigate a great deal of land which can not at present be covered by either the Vermejo or Springer system. Besides this, there are other projects surveyed: First, to collect the flood waters of the Van Bremmer, Serososo, and Ponil rivers into a series of natural lakes, each of which will hold a large quantity of water, with a dam to be built around them; second, a project to collect the waters gathered through the heavy floods which every year occur in Crow Creek Cañon. This, however, would be rather expensive and would not cover more than 3,000 acres. A third plan is to collect the waters that come down Raton Arroyo and the Chica Rica Creek and its various branches, and from the melting snows which come down from the Bartlett and Chica River mesas. This proposed system is located east and southeast of Raton, near the eastern boundary of the Maxwell land grant, and would cover 12,000 acres, which are located partly on Government land outside of the Maxwell grant.

The waters of the grant belong to the hydrographic basin of the Canadian River, that is, to its head waters; the Cimarron is only a branch of the Canadian. As to altitude, the proposed storage basin on the Vermejo River would be located at about 7,200 feet, and that at the head of the Cimarron at 8,100 feet. The area of irrigable table-land on and between the two existing ditch systems is about 75,000 acres in extent. The whole area which could be embraced in the different schemes for irrigation, now built and to be built, would be nearly 200,000 acres. The area at present under ditch is 52,000 acres, and there is in cultivation at this time under the Springer Ditch about 2,000 acres, under the Vermejo about 4,000 acres. There are also a number of private ditches on the open table-land at the same altitude. Their area of service it is difficult to estimate. These ditches are taken from the Cimarron, Ponil, Van Bremmer, Vermejo, and Red rivers on the New Mexico portion of the grant, but the amount of bottom land now under cultivation on these different creeks will aggregate about 30,000 acres. These are cultivated by different settlers, who have either bought or leased from the grant owners. There are in all about 300 families, or a population of 2,000 persons, not including the mountain and cañon farm lands. It embraces only the first and second bottoms on the rivers as far as they extend into the mountains, up to their head waters and down to the foothills. There are a number of other settlers in the Moreno Valley, Ponil, Van Bremmer, and Vermejo parks; but these chiefly depend on the rain which falls there abundantly at different times of the year. The total population of the Maxwell grant, including mines, different towns, farmers, etc., will now be about 7,000 persons. The total area under ditch is over 80,000 acres.

The climate, except in the high mountains, is mild for nearly every month of the year. Fine weather extends as far as the end of December, and only in January are there a few cold days. Rain falls abundantly in April and May, followed by the dry month of June; rain starts again in the months of July and August, thus affording as a rule the very best opportunity for good crops. During the winter the snowfall is moderate, but abundant enough to saturate the soil and give an opportunity for early plowing. Fall plowing has become the rule. The temperature is mild; the nights are cool even after the warmest days, and the heat in summer is never oppressive. The table-land altitude where the irrigating systems are located varies from 6,000 to 6,500 feet, while in the mountains where crops are raised it varies from 6,200 to 8,400 feet. At the latter altitude rains are abundant. The following statistics of rainfall and temperature during the year 1890 are taken from observations made by a weather station which is located at the head gate of the Vermejo Ditch, the altitude of which is of about 6,400 feet:

Rain and snow fall for 1890.

	Inches.		Inches.
January	0.00	August	2.12
February	0.00	September	0.95
March	0.90	October	0.41
April	4.67	November	0.37
May	1.30	December	0.52
June	0.46		
July	3.75	Total for year	15.45

Temperature.

Month.	Average height.	Maximum.	Minimum.
January	36.72	66	2
February	39.26	76	2
March	41.31	72	3
April	52.00	74	16
May	63.57	83	41
June	72.71	91	46
July	71.01	88	47
August	66.90	90	45
September	61.72	84	35
October	54.23	79	20
November	42.22	79	13
December	36.44	62	6
For the year	53.17	91	2

With regard to the July and August rains, a graphical presentation of the daily mean discharge in cubic feet per second of the Vermejo River for the seasons of 1889 and 1890, will illustrate their character. The floods of the Vermejo, as a rule, never begin before July. In 1889 there was a severe flood on the 11th of July, but there have been only exceptionally small floods for the same month in 1890. In 1889 there were no floods of any importance after the one on the 11th of July, but the next year there was a series of five floods, extending through the months of July, August, and as late as September; the one in September being the most important. It is therefore very difficult to draw a conclusion as to the amount of flood water that can be counted on in a certain month in the year on the Vermejo River. Summer observations have been made on the Cimarron or Springer system, but while the fall of the Vermejo River is 50 feet per mile, the fall of the Cimarron is not over 30 feet. The consequence is that the floods on the Cimarron River are not so heavy, as a rule, as those on the Vermejo; at the same time the floods on the Cimarron River, which derives its waters from much lower mountains than the Vermejo, are much earlier than on the Vermejo River, and mostly occur in May and June. It may be stated that while the snows on the Cimarron begin to melt and the waters of that river begin to come down as early as the month of March, they can not be counted on, for the waters do not come down the Vermejo earlier than the latter part of April and often not before the beginning of May. At the same time the flow from the Vermejo River lasts much longer than that from the Cimarron River, on account of the higher altitude of the mountains and the larger amount of snows on them. As a matter of fact, one season balances the other in the seasonal result. These observations extend for a period of about five years. There is no doubt felt of the ability to handle the flood waters and to store them in the open reservoirs now constructed, or to be constructed in 1891–1892, there having been such an immense quantity of snow in the mountains that all the reservoirs are brimful of melted snow. But by the time the summer floods come down a good deal of this storage water will have been used. It will always be necessary to gather in all the flood water that can be secured and store it in reservoirs.

The actual original cost of constructing the Springer and Vermejo ditch systems, including all the embankments, flumes, drops, head gates, ditches, and other works, has been as to the Vermejo system complete but $1.80 per acre; including recent improvements and extensions of lakes and embankments not planned at first, the Vermejo system has now cost $69,000, or $2.30 per acre of irrigable land. This appears in the annual report of the company. The Springer system cost $70,000, or $3.18 per acre of irrigable land. That includes the construction of an embankment along the largest reservoir of 4,400 feet in length and 26 feet high at the highest point, covering a lake surface of 475 acres, containing 219,000,000 cubic feet of water and 130,000 cubic yards of material in embankment. This embankment has cost $26,000 and is included in the total cost. All of the work has been done under contract and by hand; ditching machinery has not been used. The average cost of labor for man and team per day may be stated at from $3 to $4. The earthwork was let out by public tender. From 8 to 12 cents per cubic yard for prairie work and light shale was paid. The lands under these systems, including perpetual water rights, sell at present (1891) at from $20 to $25 per acre; $12.50 per acre was the first price. Party buying land with perpetual water right reserves for each 80 acres 1.44 cubic feet of water per second flowing over a weir, during the irrigating season, which is from the 1st of April to the 1st of November, a period of seven months.

The contract made with settlers states that the company has the right, after having sold all lands called for by the water supply, to turn over the ditch system to the owners of the land, provided the latter shall have paid in full for all rights. The company reserves to the community at large who are buying these lands the pro rata common and joint use of the reservoirs and lakes, which means that it does not allow them to irrigate by laterals direct from reservoirs to their individual lands, these reservoirs being considered as feeders of the whole system, to which nobody has a particular right but in which everybody has an undivided interest. At the same time the right is reserved of extending the system even after control has passed out of present hands, in case the water supply should prove to be so abundant that it can, by an extension, be made to irrigate an additional quantity of land.

The effect of such a system is this: First. That at the close of the period of land sale the ditches and works become the property of the owners of the land, with the reservation as stated in regard to surplus water which may be available in addition to the water supply set aside for the actual purchasers—the estimate mutually agreed upon on the Vermejo system, for instance, being that it will irrigate 30,000 acres; second, that no direct contact is permitted with reservoirs, but they are to be held as common property and feeders of the entire system; third, that if by filling up of the land, economy in the use of water, and an increase over the present calculation of the capacity of the storage basins a surplus of water is found, the right to increase the area of land to be covered by it is retained, provided the amount of water per 80 acres is supplied for which the agreement calls; the understanding being that if it be found the system will supply at any time an amount of water larger than may be needed by the 30,000 or 22,000 acres under each system, the right of claiming this surplus is to be reserved. The transfer of water rights is limited by the amount called for by the contract. It will be apparent that if the system as now existing is large enough to supply everyone under it before all the sod has been broken and all the lands have been brought under cultivation and under irrigation, there will be an excess of water available after all the lands have been, say, two or three years under cultivation and under irrigation.

The agreement stands good as to the individual for the amount stated in the contract, except as provided in article eight of the water agreements, which states that if the volume of water prove insufficient from drought or from any other cause beyond control, the company shall not be liable for any shortness of supply occasioned thereby, but shall have the right to distribute the water pro rata to the holders of the land. If, by economizing his water, the individual landowner obtains therefrom the means of increasing his area of cultivation, that is his advantage and nobody else's, and the constructions by individuals of reservoirs on their land to gather flood water is strongly encouraged. In any event, if the present system shall be found to hold more water than is now calculated upon, the advantage of that calculation exceeding the amount given to each landowner under the contract will belong to the company. The limit, therefore, to the individual landowner is the amount stated in the contract, and the amount stated in the contracts will become the property of the community ditch owners, and no more.

In regard to evaporation and seepage, it is found that the seepage in the natural lakes or reservoirs is quite insignificant; that, in fact, after the first year the lake bottoms are as tight as a pot. As to evaporation, experience leads to the idea that reports thereof are greatly exaggerated. Last year, at the end of October, there was, for instance, ten feet of water in Laguna Madre; the sun was quite powerful in that month, as well as in November, and even in the beginning of December; and after irrigating several hundred acres for plowing in the fall and spring, it was found that the water in Laguna Madre had only decreased one foot by the 1st of March. While there may be considerable evaporation in a hotter climate and a lower altitude, as in Mexico, Utah, or southern California, it is not of any importance, comparatively speaking, in an altitude of between 5,800 and 6,400 feet. Mr. L. S. Preston, engineer, proposes to make a systematic record of both the percolation or seepage and evaporation, as far as practicable. This gentleman is now keeping a record, twice a day, of the depth of water in all the lakes and the amount of water used for irrigation, and also of the amount of water that comes in at the head gate. The difference, of course, between the last two amounts will give the loss by percolation and evaporation. Percolation or seepage is, of course, a matter depending largely on the porosity of the soil. The bottoms of the reservoirs on the two systems are practically the same. It is a hard adobe clay that bears water, and after having been soaked becomes non-porous. The depth of the stratum that lies beneath has not yet been ascertained. The effect of water upon this adobe is to fill it up and make it non-porous, so that the bed becomes a stiff water-bearing bottom. In support of the opinion that the seepage is very small is the fact that in 1891 foundations were dug for a new dam to the outlet ditch at Laguna Madre. The bottom of the trench for the foundation was dug to a depth of 20 feet below the surface of the water in the lake and not over 50 feet away from the edge of the lake. It was 18 feet after the surface of the water was reached before any percolation into this trench was observed, so that the water had not penetrated more than 2 feet. This occurred on the Vermejo system, and shows that the clay must have retained water most effectually. It makes a hardpan that can not be penetrated. No depth has been found to the alluvial soil. No wells have been bored, and 30 feet is as far as has been penetrated. Fifteen thousand acres have been sold up to date under the Vermejo ditch system, and under the Springer ditch system 5,000 acres. Of land in the foothills and mountain regions, some portions of which are to be irrigated from adjacent rivers and others are under the natural rainfall, under the present administration 53,000 acres have been sold in all.

It is claimed by the manager, Mr. Pels, that the object in building these ditch systems was not only to sell the lands off rapidly, but to divide them in small holdings sufficient to support and make a good living for a family, with a view of increasing the population there as much as possible by an influx of good, thrifty settlers who would make good citizens. The experience has been that people, as a rule, in taking Government lands or in buying from private parties, buy more land than they can handle, and are just ready for a mortgage when they have to make a second payment, having no available means after they have done the work of farming, fencing, building houses and barns, etc. This has gradually and as far as possible led to a restriction of the amount of land to be bought by each individual. The consequence has been that deducting the Maxwell Land Grant farm, the average now owned by each settler's family on the Vermejo and Springer ditch systems will not exceed 80 acres. Lately it is found that the purchasers are reduced to 60 acres or less, which will give a good living to a family, and that several of the larger holders resell part of their lands. The board of trustees have made it a rule not to sell any tracts, whether on the irrigated systems or in the mountains, exceeding 320 acres to any one bona fide settler, except for establishing colonies, and have also made it a rule to exclude sales to speculators, and they limit themselves exclusively to sales to bona fide farmers. The limit per capita for farmers in this altitude and under these conditions varies. It is thought that a family can, as stated above, make a good living and become very well to do by cultivating an area not exceeding 60 acres. He can do with even less if he has the means of raising fruit only. At the same time the case is different where a man buys lands in the mountains along the streams. It has been the rule to sell at least half a mile across the stream, the buyer thus taking in, say, about one-fifth of irrigable land and four-fifths of hill land, which latter can only be used for grazing. The consequence is that people fence in these and use the hills to a great extent for raising some cattle, which industry, of course, has to be limited to a few milch cows on a 60-acre tract in the irrigated systems. This applies directly to the cultivation of the soil for crops and general farming purposes, not to the question of a timber or grass claim. Timber tracts are not sold and efforts are being made to preserve the timber at the heads of streams, to secure always an ample water supply below.

In this system there are practically three qualities of land: The table-land that lies open under the ditches, present and prospective; the high foothills, lands that consist mainly of more or less narrow valleys and the foothills just above them; and then the higher mountain land, which includes a portion of the stream and cañon region, has some timber, and which is largely a cattle range.

It is preferable, as a matter of economic growth and social life, that all the arable lands should be settled in small portions, and efforts are being made with that end in view. From general observation as to the land cultivated by irrigation it is thought to be more desirable to have small than large holdings. As a rule there is more made by cultivating intensively under irrigation of small parcels than there would be by cultivating large farms under the same system. Farming does not pay where a family has bought land and has to apply for outside help and borrow money in order to secure the means of cultivation. This does not apply to farming on a large and systematic scale as is done on the Maxwell farm under the Vermejo Ditch. A thousand acres have here been broken, of which 600 are in alfalfa, an expense which undoubtedly gives first-class returns, but which, on account of the heavy outlay for seed, preparing the soil, and ditching, can not be incurred by many individuals. Allowing the existence of large landholders with abundance of capital in one portion of the locality such as this, and then allowing for a considerable number of persons of moderate means and industrious habits and intelligence, and comparing the two systems as to the cultivation of the soil and the results thereof, and looking at it abstractly as to whether a number of small holdings are a large holding with large capital should be preferred, it is believed that the result would be, if other conditions were favorable, that the financial results of ten farms each of 60 acres, compared with one farm of 600 acres, however ably conducted, will show after a few years a decided advantage in favor of the ten farms. Experience in this matter, not only here but also in Holland, gives the conviction that small holdings of land only are conducive to a maximum of prosperity. Besides, the primary object has been to induce the settlement of as large a number of good, hard-working, law-abiding citizens as possible.

The policy adopted of having the ditches and reservoirs become the property of the community when the water rights thereunder are all sold is the result of deliberate judgment that the ownership and administration are best in the hands of the landowners; this plan has also been followed to a large extent in Colorado.

On several of the farms that are now being cultivated there are individual reservoirs. This is a matter that is to be encouraged as much as possible. Not only on these ditch systems, but farmers also who are located on the bottom lands near the rivers, have been informed by the manager of the company that its surveyor has been instructed to locate, free of expense to them, sites for them to build reservoirs on their lands. The object of this is to encourage them to make use of and gather all the flood water they possibly can, so as to drain at other times on the resources of the ditches as little as possible, and consequently to reserve to the community at large, in dry seasons and at times when there are no floods, the greatest amount of water that will run into the ditches. The concession is even contemplated of reducing the price of land to such parties as are willing to go to the expense of building small reservoirs on the lands they buy. These reservoirs will be filled by laterals built by the farmers, and which connect with the main ditch laterals or canals, and it is simply a matter of knowing in time when the floods arrive so as to open all the gates at the different laterals; and of that all are always advised in time by a telephonic system, which connects the head gate with the residence of the ditch superintendent and with other points of the system. These small individual reservoirs are encouraged, then, first as a means of holding the actual surplus of the farm laterals, and second all such surplus as may suddenly arise from floods or storms. The efficiency is doubtful, however, of any ditch system having no reservoirs and therefore not able to store and gather all the flood water and surplus of river water or of rains or cloud-bursts; only a storage system can supply its farm lands as well during the dry months as in the months during which the snow melts and the ditches run full. Attention should be called to the possible value of these small farm ponds or lakes in the course of two or three years. It will be found that, properly located upon the farm with a view to its natural condition and drainage, they will receive back from the soil a large amount of the water put into it for the purposes of irrigation, after it has fed the plant life; that they will be kept with water in them from the natural return to the center, such as a reservoir will make, of the water unconsumed by the plant life, applied to the surface for irrigation purposes. There are some very remarkable facts that come to light on that subject, and it will be worth while to observe what is suggested in regard to it incidentally; that the use of water adds to the conservation of water; that the use of water in irrigation increases the supply of water from the earth itself. As a natural consequence, if we have a proper reservoir, the unused water will also be drained into that reservoir after it has been applied on the surface, and it will be the ranchman next below who will get the benefit of this. This will be done by gravity, but very often that gravity will be sufficient, even in 80 acres, to make an impression on the reservoir of that 80 acres.

The products that do admirably well, grow profusely, and are paying crops on these ditch systems are all kinds of fruit trees, except, of course, the tropical and semitropical varieties, besides alfalfa, wheat, barley, oats, millet, sorghum, and all kinds of garden produce. A trial is being made of the culture of the sugar beet, and it is hoped that the quantity and quality of the saccharine matter may be satisfactory. On the Maxwell farm 350 acres of alfalfa was planted a year and a half ago, from which 1,000 tons will be cut this year; 250 acres more of alfalfa was sown this spring, which had a beautiful stand. In fact all the products of the temperate zone grow here in abundance. Magnificent apple, pear, prune, plum, cherry, peach, and apricot trees grow on Dawson's and Montgomery's ranches on the Lower Vermejo. All fruit trees do very well here. Their product has a fine flavor, nowhere excelled, and thousands and tens of thousands are now planted on this ditch system. Wheat never brings less than 30 bushels per acre, barley 60 bushels per acre, etc. All grain here is very heavy, especially oats, which always weighs from 40 to 45 pounds per bushel. All other grains yield in proportion. For raising hay this country is unexcelled, as the haying season is always accompanied by dry, warm weather. Alfalfa, timothy, and clover are raised in large quantities and yield enormously. Alfalfa gives three or four crops a year, producing from 1½ to 2½ tons per acre at every cutting. Potatoes, beets, turnips, parsnips, onions, and cabbages grow abundantly, and are of large size and remarkably fine flavor.

VIEWS OF MR. PELS AS TO WATER ADMINISTRATION.

In conversation with General Manager Pels, of the Maxwell grant, he expressed opinions on the administration of irrigation interests which have the weight of extensive personal observation and experience in such matters. Mr. Pels resided for several years in the Dutch East Indies, has visited India, China, and Japan, and is familiar with irrigation conditions both there and in California. What he says, then, is interesting and comes with considerable force:

> The system of incorporation known as the irrigation district system, which has grown up in California, has not been operated here. A great legal and litigious trouble arose there on the question of riparian rights and the rights of prior appropriators. Of this the manager of these systems is aware, but was uninformed of the fact that all of these troubles have been settled by a system of municipal or district incorporation under a system of laws. Under these laws the irrigators in any common district, being citizens as well as land owners and irrigators, have the right to form themselves into a municipal body, with power to bond, to hold property, to levy rates and taxes, to pay interest on bonds, to condemn property, to purchase property, and to construct works. The laws on irrigation in Colorado are well known in New Mexico, because they are likely to be adopted sooner or later in this Territory, where there is no legislation worth speaking of on water; but the peculiar system in Cali-

fornia has not been studied here. There is in New Mexico only the natural property right and the prior appropriation principle. The laws in New Mexico seem to be rather vague, but there has never been any trouble or litigation in that respect. California has adopted a system of thirty-two districts. This system has at once, within five years, stopped all litigation about riparian or prior appropriation or community rights by creating a new community interest. It simply says that the people of a community may form themselves into a district; they then find out the system of irrigation which will best serve the area of which that district is composed; they have then the power to absorb the private ditches and the corporate ditches, and they issue bonds to cover the cost of these; these bonds run twenty-one years and pay 10 per cent interest and the district becomes the owner, as a community, of the water, of course. It becomes the actual working owner of water and the works. It makes regulations and levies rates, and these rates are by law as applicable to those living within the area who do not use the water as to those who do; it being decided by the courts that the minority of nonusers are benefited to a sufficient degree to warrant the compelling of the paying of rates and the bearing of their portion of the burden of maintaining the district. Now, the effect of that has been to stop all litigation, and the effect is also to bring the larger capitalists, after some disputes, into harmony with the users of the water and to make them see that it is better to take the bonds and get the benefit and get rid of the works than it would be to hold them. Now, a principle of the same kind has been adopted, without any dispute between the landowner, water-user, and the corporation; and the same result has been reached in New Mexico, without the necessity of law, as that to which the California irrigators are coming to under the elaborate system of districts they have adopted. A water district has been practically established by which the community will some time own their own water works. And the limitations thereon are only those that increase the value of that community's interest.

Mr. Pels also expressed a desire to assist in making a presentation of irrigation systems at the Columbian World's Fair in 1893, by having photographs taken of both the ditch systems under his management, giving a comprehensive bird's-eye view of as much as possible of each system. The Agricultural Department will be supplied, he says, in time, with specimens of all the products raised under them, and with such other information as may be required, if timely notification be given. From time to time data relating to the progress of evolution in northeastern New Mexico as to the increase of the area of irrigation, the production and nature of works, and general statements that will show the progress of the cultivation of the soil in this region by irrigation will be furnished to the office of irrigation inquiry.

THE MEXICAN SYSTEM—FRUIT CULTURE IN THE MESSILA VALLEY.

The soil is all alluvial and is made up of silted mountain detritus. The products are the hardier fruits, such as peaches, pears, apples, etc. Figs may be raised, but not sufficiently to be valuable for commerce. Wheat, under fairly good cultivation, according to Prof. Hiram Hadley, of the agricultural college, averages 40 bushels to the acre, and oats are cut three times during the year from one sowing. The experiments with sugar cane show that this portion of New Mexico is one of the best known regions for its culture. Sugar beets will also thrive. From Rincon to El Paso the Rio Grande Valley is one of the finest of corn regions. All vegetables do well, and the gardeners have the advantage of putting products on the market three weeks in advance of the main crop. Asparagus grows wild when once started. This valley is the home of the grape, the Mission variety being the favorite. Near Las Cruces there are vineyards fifty years old that show no sign of wearing out. The average yield of Mission grapes is 10,000 pounds per acre. The Muscat, Alexander, Tokay, and Rose of Peru varieties are also planted and do well. Grapes from this region are on the market two weeks earlier than the California pick. Alfalfa yields an average of 4 tons per acre, averaging about 1 ton per cutting, but 2 tons per acre have been cut at once.

Irrigation at the present time is carried on under the crude Mexican community system, but the native population seem ready to adopt more advanced methods and to turn their rude acequias into large canals, provided only that their hereditary rights in the water are recognized and protected. Don Jacinto Armijo, probate judge of Donna Ana County, speaking for the native irrigators, desires that the ditches should be taken out by improved machinery and not by manual labor, and further declares that the people are seeking to prepare their land after the method practiced by the agricultural college at Las Cruces, and that since the establishment of that institution a general and very material improvement has been observed among the Mexican irrigators. He thinks that if the supply of water were regulated by a just corporation, assuring to the people their rights to water, or the whole placed in the hands of a system like the California irrigation districts, instead of the present community method, the people would readily accept the situation and turn over their present ownership to the better administration of a larger autonomy. The great obstacle to such an arrangement would be the opposition of the small irrigators, who, having no money to maintain their ditches, pay for their water by manual labor. These would not favor any change of system, except on the most absolute assurance of security. It is easier, he says, for these small farmers to pay ten days' labor than $5 as a tax. The district system would meet their wants.

The records of the acequias under the mayor domo's shows the following acreage in Donna Ana County that received water during the year ended June 30, 1890, and that the same was cultivated by 810 irrigators, three-fourths of whom, or 620 persons, are Mexicans:

Las Cruces, 120 terrenos of 50 acres each	6,000
Donna Ana, 50 terrenos of 100 acres each	5,000
Messila, 200 terrenos of 52 acres each	10,400
St. Thomas and San Miguel, 40 terrenos of 50 acres each	2,000
La Mesa,[*] 100 terrenos of 40 acres each	4,000
Chamberino, 40 terrenos of 50 acres each	2,000
La Union, 80 terrenos of 50 acres each	4,000
	33,400

At Colorado and Santa Theresa and from Rincon south toward Donna Ana there are 2,000 more acres. In Toulerosa, including Three Rivers, there are 2,000 acres, thus making a total of 40,400 acres watered in Donna Ana, of which over 90 per cent was actually cultivated during the year ended June 30, 1890. This estimate is very conservative and somewhat below the actual figures of cultivation by irrigation in this county. Land entitled to water in this region is too valuable to lie idle; besides, if a few large ranchers of 4 to 2 terrenos of land be excluded, the average size of the farms in Donna Ana County will be about 20 acres, all of which are intensely cultivated.

Col. Albert J. Fountain, a well-known lawyer, and a gentleman who has made a very close study of old and modern New Mexican life, says:

> The district system of irrigation as practised in California is the only innovation that the people would be likely to tolerate on the present method of community ownership of water. Their right of water runs with the land under the Mexican law; and while the system is cumbersome, yet it insures the people their water; any system that makes them pay money for what God has furnished is incomprehen-

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[*] Originally La Mesa had but 50 terrenos of 40 acres each or 2,000 acres.

sible to them. They are willing to work to build ditches and develop water, but refuse to be taxed a cent in money. If they could be brought to understand that a better system would provide their water, preserving to them all vested rights, little objection would be offered. The old Spanish dictum was that the water owed a beneficial servitude to the land, and that the sovereignty of the Government over the water was for the purpose of assuring the service. Any system, whether it be a municipal or private corporation that seeks authority at the hands of the native people of this Territory to exercise direct or indirect control over water, conflicts with the hereditary idea of sovereign governmental ownership in water for the benefit of the community of landowners. Then, again, the people fear a clash between the old legalities guaranteed to the native population by treaty and any new authority that may be created. The system now generally proposed is about as follows: We have 120 terrenos or 6,000 acres of land under cultivation in and around Las Cruces, divided among 300 or 400 persons, some of whom own 5 acres, some 100 acres or more. Under the present plan each one of these persons is required to contribute, either in labor or money, a sufficient amount pro rata to keep up the assessment for repairs. The proposition is that all of these people—and there can be no corporation unless it be unanimous—that all these people surrender their water right to certain persons, whom they shall elect as their directors, receiving in return a certain amount of stock pro rata for these rights in lieu of their present direct ownership. The amount of stock each would own would be taxed a proportionate amount to keep up the acequia. Suppose I own 5 acres, and it is put into the stock fund as $500 worth of stock. I would be required to pay 1 per cent in order to keep up the acequia. The capitalization being $100 per acre, that would be $5 per annum, and $6,000 from the whole amount of land. This sum would of course be in money, and that is the great objection. The ordinary native is willing to contribute three or four days' labor per year, but he is very loath to pay even the smallest sum of money in lieu of that labor, because his ancestors always had their water by labor, and he can not see why he should pay for what he considers his by vested right. The objection is to the method of administration and not to the merits of the proposition. Another difficulty is that this scheme does not recommend itself to the English-speaking promoters of irrigation enterprises or capitalists. The people would be the only beneficiaries by this plan, gaining thereby the power to turn 6,000 days' labor into, say, $6,000, and from this fund through their district supervisors or commissioners, purchase proper machinery, and thus lower the future cost of irrigation, besides having their work better done.

Another proposition is to take out a large ditch by private enterprise, starting some miles from the present head gate. This is to furnish water at a low rate to all who surrender their water to the ditch company. The people look on this with suspicion. However, it may be said that if these people take out their ditch without interfering with anybody else, it would be a great advantage to irrigation in this region; and it is a practical proposition, especially if they adapt their canal to the irrigation of the mesa lands. The Procita grant of 13,000 acres, just below here on the mesa, offers a very good opportunity for the investment of private capital in such a canal, and the people would offer no interference whatever. There is also a very large acreage of new land outside of their grant on which the capitalist may expend his energy to his commercial profit and the great advantage of local irrigation. The main street of Las Cruces is 20 feet above the highest ditch line, but between the town and the foothills lies a wide acreage unequalled for the production of the wine and raisin grape. Every acre of this land is worth $50, and the proposition to water it is feasible; therefore, when the ditch men come to the present owners of water rights to negotiate for their ownership, it creates suspicion in the minds of the people. * * *

In connection with the statistics presented lately by the Census Office in its bulletin on "Irrigation in New Mexico," I would like to say, and desire to be quoted, that I do not know or care where the office got its figures, they are wrong and a grave injustice to our people. The number of irrigators in this county, according to the records of election of the mayor domos, at which no one can vote unless he is an actual irrigator, for the election prior to June 30, 1890, was 810; and there are 40,000 acres in all cultivated. It is too much to say that 10 per cent of this land is uncultivated or not irrigated. Land with a water right is too valuable. As to size of farms I want to say that the largest irrigator is the "townsite company," that irrigates 600 acres. There are not a great many tracts larger than 40 acres and the average extent of an irrigated farm will be about 20 acres. As to crop values per acre, I want to say that alfalfa will bring $80 to the acre. Wheat and corn are low in average, about $20 per acre. Corn will bring $36, and grapes at 2 cents per pound will net $200 per acre. An acre of grapes or 700 vines averaging 20 pounds to the vine will at 2 cents a pound pay $280. The finer varieties, such as the Muskat and Tokay, will average per year $300 per acre. Two years ago I know they brought $600 per acre. These are facts and presented to enforce my estimate $200 per acre for grapes. Alfalfa, on June 30, 1890, was worth $15 per cured bale. In the early spring it was worth $20, and $9.50 was the lowest price paid during the year considered. These figures will hold good throughout the Mesilla Valley.

The Mesilla Valley, as dominated by the Organ Mountains, is believed to be underlaid with phreatic water. Considered in connection with the the surface supply, this will largely supplement the acreage now under cultivation. Dr. Alphonse Petin, of Las Cruces, in discussing the movement of the underflow in this valley, says that on his place, about 1½ mile out of Las Cruces, he dug a test hole 14 feet deep and 6 feet wide. At 12 feet 6 inches very coarse, black volcanic sand was found and on reaching 14 feet excavation could not be continued without planking because the water ran through the stratum so readily. He said:

> I then tried the experiment of dropping a piece of paper on the north of the hole and it floated to the south side in 2 minutes and 45 seconds. I repeated that experiment for two days until the hole caved in and noticed that the float crossed the 6-foot space more quickly on the second day by about 15 seconds, or in 2 minutes and 30 seconds. These experiments were carefully timed. This hole was not sunk in the river bed, but in a branch that went round a mound of sand.

On the mesa there are different flows of this sheet water, as can be seen in working for driven wells. The shallowest depth at which water is found, according to local experience, is 12 feet, and the deepest that is known of is 72 feet and 74 feet, but generally after a depth of 60 feet is reached the water rises to within 2 or 3 feet of the surface. There have been no observation of precipitations on the Organ Mountains and no means of estimating the rainfall. However, 18 feet of water has risen in a dry arroyo from a cloud-burst, so that the precipitation must be immense.

The plain or valley to the east of the Organ Mountains is entirely riverless, and has but a few springs. Near the white gypsum sand the water is very bad. This interval is over 50 miles wide with large deposits of gypsum, and in the white sand water can be found often at 2 feet. The evidence of a lost river is very apparent. The water near the surface in these beds is nearly as saline as Salt Lake, but the water from the black sand is pure and potable. The eruption that caused the disturbance here is about 700 years old. If a proper administrative or legislative policy were adopted plenty of water could be developed from the underflow to reclaim large areas of this country for pastoral purposes, at least. If this land, on which water would be very expensive for irrigation, was leased for pasture, sufficient water could be developed to support the stock. For instance, a stockman formed a tank on the plains, about 40 acres in extent, which has 12 feet of water in the center.

In the Mesilla Valley when cultivation has continued for a long time soil water is found most often at 10 feet below the surface, and a drive well will always have constant water at 26 feet. When you drive a pipe the first water is reached at about 10 or 14 feet in black, volcanic sand; then a very hard stratum for about 8 feet, below which an immense supply of water is found. Wells have also gone down 70 or 80 feet, developing fine soft water, which rises in the well.

Mr. S. B. Newcomb, of Las Cruces, also very familiar with this valley, states that long experience justified the assertion that the permanency of this water was assured, and the supply apparently inexhaustible. On the majority of the farms the acequia water was used for domestic purposes, there being no better water if you clarify it, as it is the melted mountain snow.

Irrigated Orchard near Roswell, Rio Pecos, Southeastern New Mexico.

THE PECOS VALLEY.

The chief engineer of the artesian and underflow investigation, in his final report, very fully covers the characteristics of a large section opening up under the construction of irrigation works, which promises to furnish very rapidly desirable homes for a considerable body of people. It is a valley of large extent, great fertility of soil, exceedingly picturesque and in its upper portion promises to become one of the wonderlands of the world; with an excellent climate, in the very center of the beet-sugar belt, and so sheltered as to have the advantage of a spring two weeks earlier even than the southern coast and San Joaquin counties of California. The water supply is abundant, the current of the Pecos being about 4 miles per hour with a flow at low stage of 1,000 second-feet. The works already constructed, or in process of rapid completion, are designed to serve at least 260,000 acres, and are so planned as to provide for a considerable extension. The area in New Mexico may readily be increased to 700,000 acres. The organizers of this enterprise have also constructed a valley railroad of 80 miles in length and built up, among other important improvements, a handsome town. The Pecos Valley and works was made the subject of critical study by the special agent during his tour of inquiry in the summer of 1891. The works required are on a large scale and the construction has evidently been thorough and workmanlike.

The northern canal is taken out at a point on the Hondo River near Roswell, N. Mex., the water at the intake of the canal being raised 15 feet by a frame dam resting on a foundation of closely-driven piles between which is carefully-tamped broken rock. The frame dam is 30 feet wide and 116 feet long, connecting at either end with earthen banks, riprapped with from 2 to 3 feet of rock. The canal is constructed (September) a distance of 26 miles, 30 feet wide on bottom, 7 feet deep, side slopes of 1½ to 1; it has a fall of 12 inches per mile and carries at its full capacity 6 feet of water. The maximum discharge is 561 cubic feet per second. In connection with the main canal there are thus far constructed 50 miles of lateral ditches from 4 to 10 feet wide on bottom and 2 feet deep. The northern canal as completed will water 44,000 square acres and under the proposed extension 58,000 square acres more, making a total acreage on the northern canal when completed of 102,000.

The dam of the southern canal is located about 6 miles north of the town of Eddy, at a point where the Pecos River has cut its course through solid limestone formation, giving an exceptionally favorable site. The dam is constructed of a loose or broken rock fill or embankment 1,130 feet long, 50 feet high at the deepest place, and rests on solid rock foundation the entire distance across its base. The back or down stream slope of the rock fill is 1 to 1, that of the upstream slope being one-half to 1, and carefully laid by hand. The front of the rock embankment is faced with sacked earth, gravel, boughs, and loose earth until the water front has assumed a slope of 3 to 1, this being finally riprapped with 18 inches of broken rock. The crown of dam is 24 feet wide. Near the eastern end of the dam is the scour gate, 4 by 8 feet in the clear, and built of masonry. Spillways to carry off flood waters have been blasted out of the solid rock near both ends of the dam, one being 13 feet by 210 feet, and the other 250 feet by 5 feet. The outlet is a cut 30 feet wide, 25 feet deep, and cut through the sold rock on the easterly side of the river, with gates about midway to regulate the flow of water. On the west side of the river and reservoir the limestone ridge curves around to the north and toward the river above; and some 400 yards from the center of the dam a broad cut has been made across it, 5 feet below the level of the crest of the dam, for the escape of surplus water in case of sudden rise, which water will flow down a ravine back of the solid rock ridge and reënter the river half a mile below. On the east side the ridge broadens out northward and has been cut in two by the river until a vertical cliff of considerable height has been formed. Against this cliff the force of the flow for 2 miles above comes squarely, and being broken by the solid hill, turns toward the dam a few hundred feet below. The lake or reservoir formed by the dam is 7 miles long, 1¾ miles wide, and holds about 1,000,000,000 cubic feet of water, enough to supply the ditch with a full head for nearly one month. When filled it gives a head of water 20 feet above the bottom of the cut through which the main canal is fed, and 13 feet above the feed gates when open.

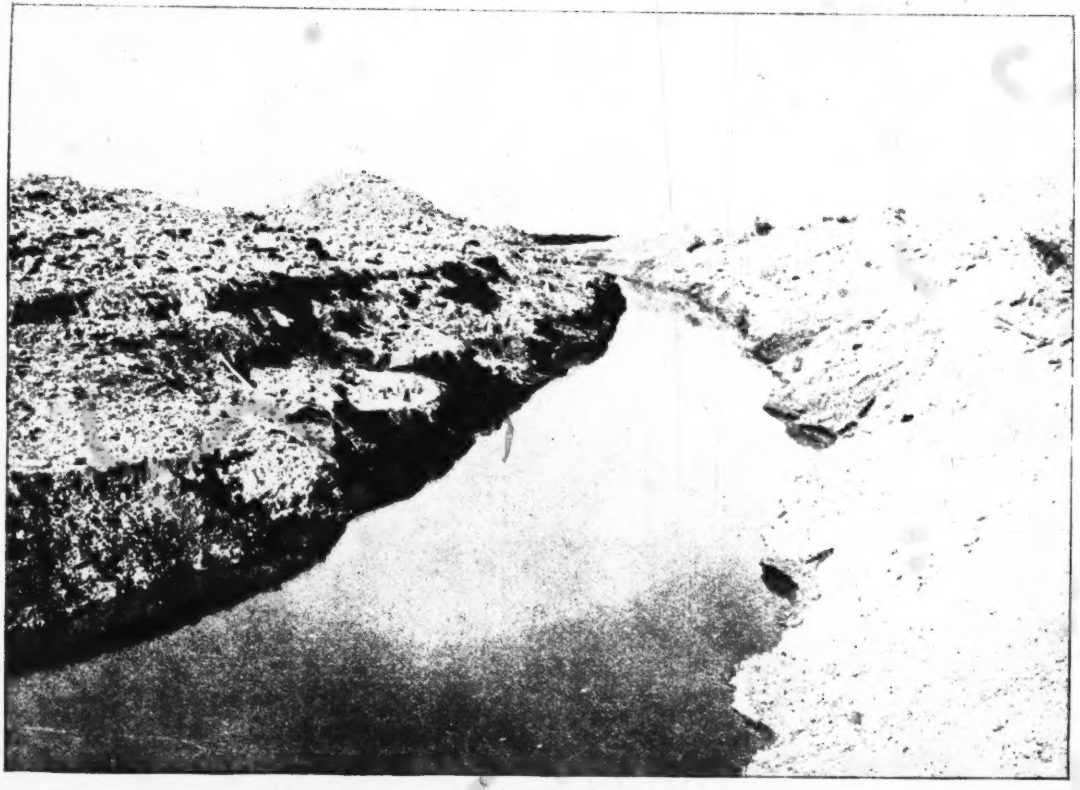
There are three canals, two on the east side of the river. The Hagerman has its head dam 15 miles below Eddy, a large storage reservoir on its course, forming an extensive lake 1½ miles long and one-half mile wide with an average depth of 25 feet. The main canal is to be extended to a total length of 25 miles, crossing by a flume to the west side of the Pecos, at a point about midway between Black River and the Delaware, and continuing southward across the last-named stream to the Texas line. A third canal is under way below the Territorial line. Other operations are in progress in Chaves County, and from part of the reclamation of the Pecos Valley by irrigation.

Under date of September 12, 1891, Charles B. Eddy, of Eddy, N. Mex., wrote the office of Irrigation Inquiry as follows:

> In regard to the acreage put into agriculture and fruit-growing I can not give very accurate data, as the country is developing very fast, and any statement would lose its value.
>
> I will say, however, that we have at present deeded over 25,000 acres of water to actual owners of land. These are bona fide payers of our water rental, and additional water rental is being taken every day. Our canal was not completed so as to furnish water until early this year, and consequently the showing as to the crops can not be a very large one for the past year, but settlers are everywhere up and down the valley clearing, grubbing and plowing their land, and thousands of acres of new lands will be sown this fall so as to produce crops early next spring. Owing to the delay in getting the canal in shape to deliver water, no effort was made to induce immigration until about the 1st of last March, when a small organization was started for that purpose. Since that date over 3,000 inquiries have been received from parties all over the county who wish to make a change of home. Settlers are now daily coming in, and from all the information received the Southwestern country will certainly receive a very large immigration this fall and winter, of which the Pecos Valley will get a good share.

From responsible parties at the same point the following statements relative to the growth exhibited there by means of cultivation under irrigation have been received. As the Pecos Valley is a new field and one of great importance, these illustrations of successful growth are given:

For instance, Thomas Stokes, of Eddy, N. Mex., raised during the summer of 1891 11 tons of sorghum (hay) on less than 2 acres of new ground, which product he sold at $15 a ton, the cash yield being over $83 an acre. Julian Smith, of Lookout, Eddy County, N. Mex., sold during 1891, during the past nine months, over $300 worth of garden produce from half an acre of ground, and has 400 pounds of potatoes left. R. M. Gilbert, whose address is Seven Rivers, Eddy County, planted in the spring of 1891 1 acre in potatoes, and gave them no fur-



Rock Cut on Curve Pioneer Canal, West Valley Line, Pecos County, Texas

ther attention whatever except to irrigate them occasionally during the summer. When he dug them the yield was over 7,000 pounds. They sold at 2 cents a pound, so that the cash yield from this 1 acre was over $200. Mr. Gilbert stated that he can raise twice this quantity of potatoes to the acre with proper cultivation.

W. W. Paul, of Lower Penasco, N. Mex., raised 211 bushels of oats on 2⅓ acres of ground. Oats are selling here for 70 cents a bushel. Cash yield, $67 an acre. G. W. Blankenship, of Eddy, sowed 12 acres of rye on September 18, 1890; cut in May, 1891; sowed millet on the same ground and cut two crops, the last on September 12, 1891, making three crops within the twelve months. The total product in cash yielded $64 an acre. John W. Poe, of Roswell, cut 600 tons of alfalfa from 110 acres. This, valued at $15 a ton, was $9,000; cash yield per acre, $80. Maynard Sharpe, of Eddy, sold $75 worth of watermelons from one-eighth of an acre of ground. An acre at this rate would have yielded $600. He raised a second crop on the same ground, but being pressed for help did not market any of it. L. M. Holt, of Eddy County, raised 11¼ tons of sorghum on 1½ acres, and 450 tons of alfalfa on 90 acres. The alfalfa would be sold at $15 a ton, making a return of $112.50 an acre.

C. W. Greene, jr., and Sam Hughes, of Eddy, raised sugar beets that have yielded 19 and 63 tons to the acre, respectively. Samples have been analyzed at the Agricultural Department, and Prof. H. W. Wiley, the chemist, estimates the probable yield of sugar from an acre of such beets at 2,000 pounds and 8,400 pounds, respectively. Negotiations are now in progress for the building of a beet-sugar factory at Eddy.

The security to stock-raising which the development of water supplies, under irrigation enterprise, has produced, is illustrated by the fact that over 500,000 pounds of wool have been shipped from Eddy since June, 1891. It is estimated that more than 1,000,000 pounds will be shipped in the following year. George Blankenship and Edward Scroggins, of Eddy, have raised fine fields of cotton during the season of 1891. Many of the stalks bore 60 to 90 bolls each. Such results can be obtained only under irrigation; they are impossible in any portion of the rain belt.

The following table shows growth made by various fruit trees, shade trees, grapevines, etc., during the past summer:

Name and address of grower.	Tree or vine.	Growth.	
		Ft.	*In.*
Witt Bros., Eddy, N. Mex	Raisin grape	16	9
Do	Apple	4	9
Do	Pear	4	8
Do	Plum	5	9½
Do	Cherry	1	9
Do	Crab apple	1	8½
Do	Mulberry	1	8
F. G. Campbell, Eddy, N. Mex	Black locust	8	7
G. W. Blankenship, Eddy, N. Mex	Apple	3	11
Do	Apricot	5	8
Do	Peach	3	9
Do	Box elder	6	1
Do	Mulberry	7	8
Do	Lombardy poplar	6	2
Do	Castor bean	8	4
James Hogg, Seven Rivers	Peach	7	2
Do	Cottonwood	16	3
R. M. Gilbert, Seven Rivers	Osage orange	14	7
Do	Native willow	16	5
Do	Pecan	6	2
Do	Black walnut	4	11
Do	Plum	8	1
Do	Mulberry	6	4

Witt Brothers have several cottonwoods 9 years old that are 62 to 64 inches in circumference, and over 60 feet high. Mr. Hogg has a peach tree 3 years old from the seed that is 3½ inches in diameter and 17 feet 5 inches high. He has a cottonwood that is 4 years old that is 28 inches in circumference. Mr. Gilbert has a pecan tree 6 years old that is 24 inches in circumference, and 22 feet high. He has a black walnut tree 3 years old, from the seed, that is 12 inches in circumference, 11 feet 10 inches high, and that bore several walnuts this year. Maynard Sharpe, of Eddy, has two peach trees 2 years old from the seed, that bore and matured seven peaches this year. He has one apple tree 2 years old from the seed that bore three apples the past season. These facts and figures have been compiled with great care, and the measurements are absolutely correct, as correspondence with any of the parties will make apparent.

UNDERFLOW WORKS.

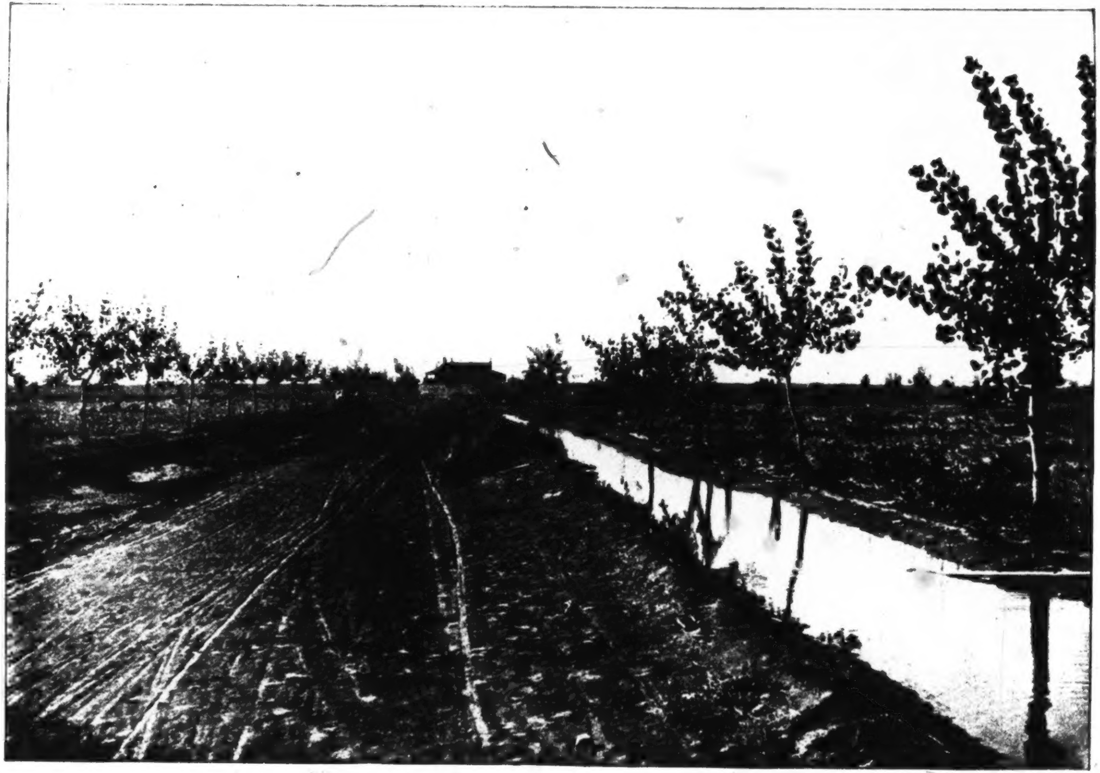
The Mimbres River heads in the Black range in the northeastern part of Grant County, N. Mex., and flows in a southerly direction. During the flood season its waters flow to a point some 10 or 12 miles southeasterly from Deming a distance of about 90 miles from its source before sinking, but during the dryer portions of the year they disappear in an underground channel at a point about 40 miles from its source. The lands proposed to be irrigated are a portion of an extensive plain extending from the proposed reservoir sites for 60 miles south to the Mexican border. This plain is transversed by three lines of railroad, the Atchison, Topeka and Santa Fe, the Southern Pacific, the Deming, Silver City and Pacific, and a proposed line now partially graded to connect Deming with important Mexican points on the south. This tract is considered to be the only agricultural land that can be made available from the Rio Grande on the east to the Rio Gila on the west, a distance of 200 miles. This enterprise and another one of a similar character in the same section are important as experiments, and for that reason the following account is given.

According to Mr. L. Clapp, jr., of Las Cruces, the civil engineer in charge of the enterprise:

> The flow of the stream was found to be 90 cubic feet per second, by measurement taken on March 14, 1891; about five weeks later it was found to be the same; on another visit in May it was estimated at one-half, and I believe that a fair estimate of the average discharge of the river at the point selected would be 90 cubic feet per second, exclusive of flood waters. This would give an annual discharge of 2,838,240,000 cubic feet.

The river bottom proper is here 900 feet wide. It shows indications of being frequently flooded from 1 to 3 feet deep. Mr. Clark says he was informed that the bottom is covered about one month on an average during each year. Assuming that this only holds good for twenty days, there will be a discharge of 5,184,000,000 cubic feet to be added to the normal total given, making 8,022,240,000 cubic feet as total annual discharge of the surface flow.

The indications for a large underflow are exceptionally good. The lower Mimbres is believed to be an underground river; in that case the surface water is only the surplus appearing after the underground channel is surcharged. Soundings taken across the valley at King's ranch show the bed rock to be from 8 to 12 feet below the surface; lying on the bed rock a layer of course gravel and bowlders from 2 to 4 feet in thickness are found, then sand and gravel from 3 to 4 feet



Residence and Orchard near Eddy, New Mexico.

Trees all planted in 1890.

and surface soil from 4 to 6 feet in thickness. The average depth of bed rock from the surface is 11 feet, and the average depth of this water, bearing stratum is 7 feet. At a width of 4,000 feet Mr. Clark estimates a cross sectional area of 28,000 square feet. Assmming this to be 20 per cent water, we have 5,600 square feet cross sectional area of the underground stream; and a flow of 1-100 foot per second would give a discharge of 56 cubic feet per second, or 1,766,016,000 cubic feet per annum; this added to the quantity previously estimated would give a total annual discharge from all sources of 9,788,256,000 cubic feet, or 224,710 acre-feet.

The drainage area of the Mimbres River from its sources to the point selected for the proposed work is at least 500 square miles, and the average annual rainfall at Fort Bayard in the foothills of the Black Range is 21 inches. But the rainfall in the mountains at the source of the river is considerably more than this. Going down the valley it decreases until at Deming, on the plains, an average of but 10 inches is recorded. Mr. Clark therefore assumes 20 inches as a fair average for that portion of the valley tributary to the system.

"Drainage ditches," says Mr. Clark, "show a small but constant flow, and with this result from the surface of the water-bearing strata there are the strongest reasons for believing that the result to be expected from a bed-rock dam, bringing all the water to the surface, will be equal to or much greater than the estimate made."

Again, the large number of wells scattered the whole length of the valley and on the plains on either side, especially at Deming and in its vicinity, show a large body of water to be present near the surface, something very unusual on similar plains in the arid regions. The wells at Deming average about 40 feet in depth and up to date seem inexhaustible, showing no difference in volume during different seasons of the year or different years, indicating a constant and uniform flow.

ANSWERS FROM CORRESPONDENTS.

The following data have been compiled from answers received to circulars sent by this office:

DONNA ANA COUNTY.

Las Cruces (post-office), Dr. Alphonse Petin and A. E. Blount (October, 1891):

Average cost per acre in vicinity for preparing land for cultivation under irrigation, from $4.50 to $25; in the valley, where mesquite grows, $7; on the mesa, $4.50.
Average cost per acre for irrigation works, ditches, etc.: On level lands, from 50 cents to $2; from $1 to $2.50 on rolling land.
Cost per acre for annual maintenance and repairs, 25 cents to $1.
Area under ditch, 21,000 acres; Las Cruces, 7,000 acres; Donna Ana and Messilla, 14,000 acres. A. E. Blount reports 90 acres under his own or neighborhood system.
Products: Alfalfa, fruits, grapes, wheat, oats, corn, barley, and vegetables.
Value of product per acre: Cereals and alfalfa, net, $20 to $25; crops separate from grazing or forage, $15 to $20.

GRANT COUNTY.

Deming (post-office), R. S. Coryell (September, 1891):

All irrigation in neighborhood done by means of water raised by means of windmills from wells averaging 50 feet deep, and each irrigating an average of 1 acre, the general product being either fruits or vegetables.
Average cost per acre for preparing such land for cultivation, $5.
Average cost per acre for maintenance and repairs, $1.
Average value of such product per acre, $100 to $250.

L. Clapp, jr., C. E., of Las Cruces (September, 1891):

Lands along the Rio Mimbres, southwest section, especially adapted to fruit growing, which is also the best paying product. Local systems of irrigation are of poor construction, apportionment of water inaccurate, and its use extremely wasteful. The main problem is one of storage, covering 2,000 acres, with estimated storage capacity of 40,000 acre-feet of water; there are also in vicinity two arroyas available for storage of about 6,500 acre-feet, giving a total storage capacity of 46,500 acre-feet. Storage is needed for supply only for certain months, and by proper regulation of distribution and use the net irrigating capacity would be 60,000 acre feet, after deducting 25 per cent for seeppage and evaporation and 10 per cent for the time when only a partial supply is drawn.

Estimated cost of the works necessary would make the cost per acre-foot of water $6.45, or not to exceed $7. This would not be excessive, as similar lands, 75 miles east, with water rights, are valued at $50 to $125 per acre.

[The project reported by Mr. Clapp as in process of development seeks to utilize the Rio Mimbres at the point to the north of Deming, where the river disappears from the surface. It is estimated that by reaching bed rock and constructing an earth and rock dam a reservoir can be constructed.]

SAN JUAN COUNTY.

Bloomfield (post-office), Lewis R. E. Paulin (September 17, 1891):

"San Juan South Side Canal Company": Water supply, San Juan River; unlimited supply.

Works: 12 miles main ditch; 10 feet on bottom, 14 feet on top, decreasing as water is drawn out; two head gates; two overflow gates; a number of underflow gates (for sluicing out sand). No reservoirs or dams.

Cost of main ditch, about $13,000.

Area under ditch, 4,100 acres tillable land; other rough land, 1,300 acres.

Area under cultivation, 440 acres.

Cost of water supply to user per acre, $15.

Annual rental cost, $1.50 per acre.

Farmington (post-office), William Locke (September, 1891):

Water supply: Las Animas River.

Works: 6 miles main ditch; 7 feet on botton; no reservoirs or dams.

Cost per mile of ditches, about $400.

Area under ditch, 1,140 acres.

Area under cultivation, 600 acres.

Cost of water supply to user per year, $4.

[No artesian wells in locality; all irrigation done by ditches from streams.]

Farmington (post-office), C. H. McHenry (September, 1891):

Chief water supply: Las Animas River; length of main branch, 110 miles; average fall, 25 feet per mile; average width, 100 yards.

Mileage of ditches: About 100 miles of ditches taken out of Las Animas River; main ditches, top 6 feet, bottom 4 feet; no reservoirs or dams.

Average cost per mile of ditches, about $500.

Area under ditch, about 320 acres for each mile of ditch.

Area under cultivation, about 160 acres for each mile of ditch.

Cost of water supply to user per acre, $1; annual rental cost, $1.

SAN MIGUEL COUNTY.

Las Vegas (post-office), J. A. La Rue (September 24, 1891):

Water supply: Mountain streams (subject to floods; at lowest stage from 500 to 600 inches).

Works: 13 miles main ditches, 2 feet on bottom, 4 feet on top; laterals fully as many miles; small rock dams, which are frequently destroyed by the floods; no head gates or reservoirs.

Area under ditch, about 5,000 acres; under cultivation, 500 acres (not more than one-half the area under ditch fit for cultivation).

Average cost per acre for irrigation works in neighborhood, from $2.50 to $4 (works generally crude and unstable).

Average cost per acre for preparing land for cultivation by irrigation: Experience of writer in irrigation confined to narrow valley of mountain stream where the area of arable land is small compared to the area under ditch; cost him $5 per acre to level and irrigate his land.

Cost per acre for annual maintenance and repairs in locality, $1 to $1.50.
Chief products under irrigation: Principally alfalfa, some corn, and vegetables.
Yield of alfalfa per acre, 3 tons.

Las Vegas (post-office), The New Mexico Land and Irrigation Company.

Water supply: Canadian River Irrigation Works; about 15 miles ditches, varying sizes, commencing about 20 by 15 by 4.
One dam 100 feet long, 15 feet high, one head gate.
Area under ditch, 3,000 to 4,000 acres. Under cultivation, 500 acres. (Company has prepared for cultivation by irrigation about 1,500 acres of bottom lands heavily covered with sacaton, at a cost of about $1 per acre for clearing.)
Estimated cost of works, ditches, etc., per acre under this system, $10.
Products: Alfalfa, corn, sorghum, and oats.

[Company has in view the construction of several other irrigation plants (the Angostura plant already constructed); also propose construction of several surface-water reservoirs, to irrigate from 300 to 1,000 acres each, and inclose map, etc., of their works.]

Las Vegas (post-office), E. F. Hobart (Santa Fé), engineer (U. S. surveyor-general); Gallinas Canal, Water Storage and Irrigation Company (September 8, 1891).
Water supply, 1,000 inches from Gallinas River (at Las Vegas Hot Springs).
Works: Dam 5 feet high, 100 feet long; 6 miles ditches 2¼ feet deep, 5 feet wide at bottom; fall 6 feet per mile; one reservoir, area 30 acres, formed by embankment 15 feet high, one-half mile long.
Cost per mile of ditch, $400 (6 miles, $2,400); cost of reservoir, etc., $2,600; total, $5,000.
Area under ditch, 5,000 acres; under cultivation, 500 acres.
Cost of water supply to uses per acre, $10.
Also, Onava Canal Company (Las Vegas), E. F. Hobart, engineer.
Average cost per acre for preparing land for cultivation, $5 (breaking, $3.50; fencing, $1.50).
Average cost per acre for irrigation works, ditches, etc., $2 to $5.
" " " " " maintenance and repairs, $1.
Staple products, at Santa Fe, all fruits of temperate zone.
Staple products, at Las Vegas, all grain, etc., of temperate zone.
Value of products per acre: Fruit, $400; grain, etc., $40.

Census Bulletin No. 60, F. H. Newell, special agent, gives the following statistics:

Number of farms	4,174
Number of farms irrigated	3,085
Average size of farms irrigated (acres)	30
Average annual value of products	$12.80
Irrigated area (total) in acres	91,745

NOTE.—Dona Ana County, 275 irrigators; 11,051 acres irrigated; 130 acres average size of farms; $8.82 average value of irrigated product. Santa Fé County, 123 irrigators; 1,358 acres irrigated; 11 acres average size of farms; $14.22 average value of irrigated product.

NEVADA.

This State occupies an elevated plateau in the northwestern portion of the Great Basin, bounded on the west by the Sierra Nevada Mountains, and on the east by the Wasatch range and the Salt Lake Basin. It has an altitude above sea level of from 800 feet, at its southeast boundary on the Colorado River, to nearly 7,000 feet at its northern boundary, averaging about 4,000 feet. It is traversed in a northerly and southerly direction by high parallel ranges of mountains, some attaining to the height of nearly 12,000 feet above sea level. These are separated by valleys varying in width from 5 to 25 miles. Some of the valleys are broad depressions or sinks, which, during wet seasons, are partially overrun by water and form shallow lakes. During the summer season these become dry and seem to be alkali flats and desert wastes; they are, however, valuable for their deposits of mineral salts, etc.

Its boundaries commence at the northwest corner of Utah Territory, and the southern line of Idaho at the intersection of the thirty-seventh degree of longitude west from Washington (114° 3′ 0.57″ west from Greenwich), and in latitude 42° north; thence running west along the southern line of Idaho and Oregon to longitude 43° west from Washington (120° 3′ 0.57″ west from Greenwich); thence south along the eastern line of California to latitude 39° north, which falls in the southeastern part of Lake Tahoe; thence southeasterly along the California line to the point of intersection with the Colorado River, in latitude 35° north, and opposite Fort Mojave; thence north and easterly up the center of the Colorado River to its intersection with the thirty-seventh degree of longitude west from Washington, which is the western line of Utah Territory; thence north along the said western line of Utah Territory to the place of beginning, containing within the said above-described boundaries 112,090 square miles, or 71,737,600 acres. An approximate classification of this area gives the following divisions:

[From State Surveyor-General's Report, 1890.]

	Acres.
Water area	1, 081, 600
Forestry*	2, 000, 000
Grazing	30, 000, 000
Agricultural lands†	20, 000, 000
Mineral lands	15, 000, 000
Saline, borax, niter and sulphur deposits, alkali flats and deserts	3, 656, 000
Total	71, 737, 600

* Compiled from the report of Commissioner General Land Office for 1887.

† The agricultural areas may be subdivided as follows: Irrigable lands, about 6,000,000 acres; non-irrigable lands, about 14,000,000 acres.

The State surveyor-general says of the climate that the State—

> lies in a belt that contains all temperatures, from that required to grow cotton and cane to that necessary to the hardening of oak or ash. Through all sections there prevails that dryness of atmosphere peculiar to this region. In the absence of dews and moisture malaria does not exist in this clear, dry atmosphere. The days are mild and pleasant; the sunshine, so clear and bright, gives cheerfulness everywhere. The nights are cool and invigorating; never sultry or close. On account of the lack of humidity, the extremes of heat and cold are not so perceptible as in moist climates. No heat is oppressive in any part of the State. Summer evenings are always cool and pleasant, and serve as a tonic for the following day. In winter the mercury falls at times to zero, and in some localities much below, but with all that the winters are never severe, and many days—at times, months—are like spring. Light thunder showers occur in the summer months, leaving a delightful, cool, and refreshing atmosphere.

In a recent report (1891) the State board of trade says:

> Land in Nevada that can be reached by water is certain to produce a good crop. Whatever grows here grows to the limit of quality. There is no rust on the straw nor weevil in the wheat. Apples and potatoes grow to perfection, while grapes, plums, pears, and all kinds of small fruits do as well here as anywhere.
>
> At New Orleans and other great fairs, wheat from a Nevada ranch and potatoes from a Carson River farm were awarded a first premium, and a dozen varieties of apples were awarded prizes. Nevada honey has taken the first prize at the California and Ohio State fairs, at the Mechanics' fair in San Francisco, and everywhere it has ever been shown. Tobacco and cabbages from Glendale also won premiums at New Orleans. Wherever there has been careful cultivation there has been successful farming. Last year, from 40 acres of ground which had been sagebrush land there was cleared $3,750, and nothing was planted but wheat, potatoes, and hay. With water for irrigating, the ground keeps on raising hay all summer and never fails to raise three crops and pasture for fall feed. Last year Mr. George Alt, of Glendale, put 15 acres of his ranch in vegetables. He raised off half of it 130 tons of potatoes, which sold for 1¾ cents per pound readily. On one-half an acre he got $700 worth of celery. One acre in cauliflower paid $1,000, and those who used it said it was as good as the best they ever saw. He sold 40 tons of cabbage at 1¼ cents per pound, from 1¼ acres, besides other things, such as turnips, beets, etc., that the land produced. Mr. Alt says he knows, by the orders he had, that he could have sold a thousand tons of produce if he had had it. A close average of the yield of alfalfa for several years past would be 4 tons to the acre, worth from $4 to $7 per ton, according to accessibility to market; of potatoes 8 tons, worth $20 a ton; of wheat 20 bushels, worth $1.05 per bushel; of barley 35 bushels, worth 85 cents per bushel; of oats 50 bushels to the acre at 60 cents per bushel.

The governor, surveyor-general, and secretary of state, and other well-informed citizens of Nevada state that a great change has taken place in the sentiment of the people of that State as to irrigation during the past two years. The district or storage law is somewhat imperfect but very simple in its provisions. All that is required is to get a petition signed by two-thirds of the resident taxpayers, and to have the lines of the district marked. It is practically based on the California laws, and the districts formed will maintain a municipal organization. The people elect the commissioners by ballot, who decide what type of works shall be erected, while the electors reserve the power to vote bonds. The officers elected devise the plans for the control. Rates are levied upon the users of the water to pay the bonds and interest. The State legislature was necessarily unable to consider the question of taxing the users of the water on the public lands; and a bill was therefore introduced in the United States Congress, which it is to be hoped will become a law, to allow the settlers on public lands to be held liable for water taxes in irrigation districts. This would, according to the State officers, wonderfully improve the situation in Nevada. If it were law to-day there would be no difficulty in organizing the districts, because the organization of the latter would bring settlers. There is little agricultural land held in Nevada under the homestead law, but the lands they are now seeking to irrigate are held by private individuals under purchase from the State.

The Humboldt Valley has the largest area of land capable of irrigation. The Truckee and Carson rivers are of course the most easily available streams, and possibly the Walker. The Carson system is the most available because there is always water enough in the river to irrigate all the cultivatable area. There are about 751,000 acres that can be irrigated in the Carson Valley, and about 90,000 in the Truckee. There are already some considerable areas reclaimed in both valleys, with high cultivation at some points. In the Carson Valley there are two reservoir sites owned by Mr. Newlands, who is willing to turn them over to the State or the irrigation districts. These two are in Douglas County; there are two or three others in Washoe County, one in Churchill County, and one in Lyon County.

On the Carson is, first, the proposed Long Valley dam; next, the middle reservoir and lower reservoirs. It is also proposed to irrigate from Tahoe and Donner lakes. At the headwaters of the Little Humboldt there are some fine sites. The area fit for irrigation in the Truckee would be readily made available upon the organization of an irrigation district. Since the visit to Carson by the special agent this has been done. An organization has been authorized and the State Board of Trade has appointed a member to supervise the proceedings. The pending proposition was to embrace as many towns as possible in order to get the largest amount of taxable property in the district, so as to make the bonds more marketable. Mr. Newlands has proposed that the principal part of the State public lands be appropriated for the benefit of the districts. These are selected from the Government lands donated under special act in favor of Nevada. There is no considerable area of other public lands that are now available for irrigation districts except in the neighborhood of Wadsworth. The Humboldt basin is divided into several districts. There are sixty-three basins on the Truckee, Carson, and Humboldt, and in northern Nevada on the Owyhee River and its tributaries there are many more. It is perfectly feasible to reclaim all the arable lands on the Owyhee. In the southern and central portions of the State there is no great amount of water outside the Colorado River, but there are numerous small streams whose flow can be conserved; besides which there are many springs and a number of standing bodies of water, such as that in the Smoky Hill Valley.

No bonds have as yet been authorized or offered. The amendment of the constitution has been advocated so as to allow the school funds to be used as a guaranty of interest on the bonds. That school fund now amounts to $1,100,000. This proposition, said the governor, should be adopted for the reason that if the State is worthless what is the use of an idle school fund, and if these securities are worth anything why not loan on our own funds. If it is undertaken to invest this fund in the bonds of other States it is found that the rate of interest is very low, and nobody desires to borrow very largely, while the districts present an opportunity of enterprise considered perfectly safe, and they are willing to pay large interest. It is greatly to be wished that the power existed to invest this school fund in the irrigation districts.

Pastoral lands in the State are owned by a few parties in large tracts, they having got possession of it through indirect conveyances from the State.

In writing of crops for irrigation in Nevada there are a great many things to be considered—market, transportation, etc., all cut a large figure. Grain and potatoes can be produced better than is possible anywhere else, and they can be raised with a limited amount of water. All

Alfalfa Fields from the Sage Bush by Irrigation, Wadsworth, Nevada.

the root crops, cabbage, onions, etc., can be raised in abundant quantities. Nevada has early and late frosts, which are against it in fruit, but does not affect grain or root crops. In the southern part of the State cotton can be raised, also tobacco, sugar; in fact, Nye County produces practically the same crops as San Bernardino County, Cal. The temperature is even warmer than in San Bernardino.

The development of these crops by irrigation would greatly stimulate mining interests, and at the same time cheapen the necessities of the miners. It would at once create large products and a home market. This fact seems to be overlooked by almost everybody. They say, What is the use of raising grain when there is no market? In Nevada irrigation would create its own market by the mining development that must follow irrigation, in that way creating the very best of market.

The State surveyor-general discusses the subject of interstate waters in this wise:

> As to water that rises in one State and flows into one or many other States—it is my opinion that under present law it will almost be impossible to prevent collision between the States. It would be a clean cut fight between them, and to a certain extent would be the same as an international problem. The United States is the only party who can effect a just division of the waters, both national and international, between the different irrigation interests. It is the history of all irrigation litigation that the man highest up the stream has the best chance to use the water.

R. L. Fulton, of Reno, Nev., secretary of the State Board of Trade, one of the best informed as well as conservative citizens of that State, reports to the office of the irrigation inquiry in relation to the organization of an irrigation district in the Truckee Valley, as follows:

> The proposed Truckee River district is to extend from the State line between California and Nevada to the east end of the valley, and will embrace, of taxable property, $4,000,000. The present purpose is to issue bonds sufficient to secure the ownership, in the district, of such of the storage sites in the Sierra Nevadas as can now be obtained, but not to immediately make use of them. The sentiment prevails that the ownership should be secured now rather than to leave it to a time when their value may be enhanced by the pressure of population and the needs of the people. On the west, at a high altitude, there is one of the great snowfalls of the world, and on the east stretches a large area of very productive land. To bring these two together is the problem with which western Nevada has to deal. Fortunately, many places in the high Sierras are to be found quite well adapted to the storage of water.
>
> First, we have Lake Tahoe, an inland sea, lying at an altitude of over 6,200 feet, with a surface of 190 square miles. From this flows the Truckee River, through an outlet, where a dam could be constructed for a few hundred dollars, by which all the water can be stored that will ever be required. Under present arrangements Lake Tahoe is used by a company engaged in lumbering; the stored water made servant to them first, afterwards coming down to the farmers in an incidental way. The district can not obtain control of this at present, but probably will at some future day.
>
> Second in importance to this is Donner Lake, which lies in a depression of about 6,000 feet altitude, with a water-shed capable of filling it to a height of 20 feet every spring. It is 3 miles long and half a mile wide, and the outlet has been lowered 4 feet; so when filled the reservoir represents a depth of 24 feet of water, capable of flowing a stream equal to 10,000 miner's inches. With these there will be no danger of a drought on all the land at present under cultivation in the Truckee meadows. It is one of the sites which is open to purchase, and will be covered by the operations of the district when put into practice.
>
> Independence and Webber lakes are valuable storage sites used at present by lumber companies in their operations, but not embraced in the present plan of the Truckee district. In addition to these lakes there are a number of grassy flats now used as mountain dairies, from a few hundred to a few thousand acres in extent. Most of them have narrow outlets, through which living streams of water run. The most important of these are Sardine Valley, Henness Pass Valley, and Wheeler Valley. Water can be stored in all these to great advantage, and the district will undoubtedly desire to control them and hold them for future use.
>
> These future reservoirs, having a dam already constructed to a height of 12 feet, and a canal to a depth of 4 feet, can be secured by the district at an outlay of less than $70,000. It is not proposed to build canals to carry water to apply directly to

the land. This work, the people think, can be safely entrusted to private enterprise. The storage is held to be a proper public charge, as it will add to development. The district bonds will draw 6 per cent interest, and will be based upon the entire taxable property in the district, which will aggregate up to nearly $4,000,000.

On the Carson River a district embracing the whole basin is being organized, with a taxable property of $5,000,000. The facilities there are not so great as on the Truckee, but after the water is stored it will prove far more useful. Streams therein lie more nearly on a level with the surrounding country, so that long and expensive canals are not necessary. The land is very rich and stretches away in level valleys free from rock and alkali. Many hundreds of thousands of acres could be reclaimed at a nominal cost. A series of valleys extend from one end of the river to the other, and the water will be used over and over again. The Carson River has half a dozen mills where hundreds of stamps are engaged in crushing ores from the Comstock mines. Upon the supply of water in the Carson, therefore, depends the prosperity of Virginia City, Gold Hill, and Silver City. When the water is too low to turn the wheels the production of ore must cease and large numbers of men lie idle until the streams rise again. This can be obviated by the construction of a dam at Long Valley, where the water will be used first on a rich and fertile region lying in Douglas County, Nev. As it winds back into the stream it will maintain a regular supply to go through the mill wheel, after which it can be used in Lyon and Churchill counties for crops. Near the town of Carson another reservoir site can be made use of, and still below one in Churchill County is available; but it is thought that the Long Valley reservoir will be the only one needed until there is a larger increase in the population of western Nevada. The district will probably be bonded for $200,000 at first, which will secure the ownership of most of the land with these reservoir sites and construct the Long Valley dam. The interest on this will be about $12,000 a year, making a tax of more than 2½ mills on the dollar; so that a man paying on $10,000 taxable property would not have to bear an increase of more than $25 a year. This will be nothing in comparison with the benefits that he would receive.

On the Walker River there is abundant land and ample facilities for storage, which must be in demand in the near future.

The Humboldt River furnishes one of the greatest opportunities in America for irrigation enterprise. It is 300 miles in length, running through rich lands, and with its tributaries offering a hundred sites for reservoirs. Districts are talked of, and will, no doubt, be formed soon.

At a State irrigation convention held in Carson, statements of interest relative to the irrigation work and possibilities of Nevada were made, from which extracts may properly be given. Hon. Wm. M. Stewart said:

> The limit of agriculture in this State will soon be reached unless the water attainable for that purpose can be stored, economized, and equitably distributed. There must be unity of action in the storage and distribution of water. Private ownership of water rights among a large number of persons is wasteful and expensive. Many small ditches lead to a great waste by evaporation and seepage, and make large annual expenditures necessary to keep them in repair. No individual can afford to construct expensive storage reservoirs for the benefit of the public, and what is everybody's business is generally neglected by all.
>
> The difficulty of determining the respective rights of numerous claimants to a stream where questions of priority of right and the extent of the appropriation is involved is very great. A person desiring to irrigate land may come to the conclusion that there is ample surplus water unclaimed in a stream for his purposes, but when he has constructed a ditch he invariably finds himself in dispute or litigation as soon as the stream runs low or is decreased in volume by drought. If an irrigator attempts to enlarge the supply of water by storage he immediately finds himself in dispute with prior water claimants on the stream as to whether the water flowing down to his ditch is the natural flow or an addition to such natural flow occasioned by storage. Litigation naturally follows. The result is that at least nine-tenths of the water runs to waste which might be utilized to irrigate. I know of no instance where the water for irrigation has been well economized where there were numerous claimants to the water acting independently of each other.
>
> The most satisfactory plan ever adopted, where there is a community of farmers to be supplied from a common source, is the formation of a municipal corporation to own the water and distribute the same among the irrigators.

Mr. Stewart further stated the difference between the California district law and that of Nevada, as follows:

> The Wright law provides for the purchase or condemnation of all water rights and other property necessary for the use of the district. Our law provides for the

purchase of all property necessary for the district, including water rights, and the condemnation of rights of way and reservoir sites, except existing water rights. As the law now stands, the question is whether immediate action shall be taken looking to economy in the use of water and the extension of agriculture in this State, or whether the whole subject shall be indefinitely postponed.

Irrigation districts are not new. They exist in almost every country where irrigation is practiced, and must exist if the water is to be economized and the largest possible extent of the available land utilized by irrigation. The four principal rivers of this State furnish ample water to irrigate sufficient land to support a population of from half a million to a million of inhabitants. Take the Truckee River as an example. Would it be an unreasonable estimate to say that sufficient water could be stored for use when needed to irrigate half a million of acres of land, which is now the amount irrigated in all Utah? The Truckee Valley and the valleys immediately north, which are equal in fertility to the Truckee Valley itself, comprise about 150,000 acres. By extending the district to include the region about and beyond Wadsworth within the flow of the waters of the Truckee, it would take in a very large area of land susceptible of irrigation. With 150,000 acres of land, all to be irrigated and cultivated, and the town of Reno as a basis for taxation, would there be any difficulty in negotiating long-time bonds at 5 per cent per annum interest to the extent of from one to two millions of dollars? Two millions would involve the payment of $100,000 per annum in interest at that rate.

What could be accomplished with that amount of money, and how could the rights necessary for the formation of the district be acquired? There is but one way to accomplish this desirable end under existing law. If all the owners of water rights on the river would fix a price upon such rights, at which they would sell them to the district and receive their water from high-line canals free of charge, except the necessary taxation to pay interest on the bonds and the cost of repairs of the water works, the success of the enterprise would be assured. There could be no doubt that the necessary rights to give the district the use of the lakes as reservoirs could be acquired by purchase as fast as needed, and that the landholders would fix a maximum price upon their lands, with easy conditions of payment, so that the entire district could be speedily placed in the hands and ownership of actual settlers. The owners of water rights on the Truckee could safely enter into such an arrangement; because if only 150,000 acres of arable land were at first included in the district, there would be ample water for all, and no farmer need have the slightest apprehension of a deficient supply. After it was ascertained by actual experiment that more land could be irrigated, the district could be extended and more taxpayers included.

Mr. Stewart then proposed the appointment of a committee of water-right owners, with the view of consulting other such owners and arranging a basis of sale of the same to the proposed districts, so that all may thereafter—

Take water in common with their neighbors, to be distributed by a municipal corporation. If that is practicable, you do not want any law of condemnation. You do not want to enforce it either, and it will be a voluntary act. If the persons owning the water rights will sell them for a reasonable sum, then the public can maintain and utilize them and distribute the water. The public must have them, but you can not take them away. It is a right they have acquired and it is recognized by law. The water will be under one management and will not be wasted. Litigation would never stop as long as individuals owned the water rights, because it is so necessary to know how much water they are entitled to take. If you store the water, there would be constant litigation to know how much water you are entitled to take resulting from your storage and how much resulting from the natural flow. To make this a success the water must belong to the public. There has never been a successful operation, where the greatest possible amount of land was cultivated, without the water belonging to the public. They found this necessary in California, and you will find it necessary here. You can not afford to have the water wasted in numerous ditches. You want to have it put upon the greatest possible amount of land.

Mr. Francis G. Newlands, in the course of a lengthy address, said:

The Humboldt River spreads almost from the eastern boundary of the State to the western, running from east to west, its waters falling into Humboldt Lake, called the Sink of the Humboldt—wrongly so called, because of the popular idea that once prevailed that the waters which flowed from the Humboldt into this lake sank into the bowels of the earth. As a matter of fact, they are drunk up by the sun.

The Humboldt flows with a full current until the middle of June or July. Farmers, however, hesitate to extend the irrigable area, because they are assured by experience that in June or July the flow of the river will be scanty and that their crops will not come to maturity, particularly the second and third crops of alfalfa. Hence irrigation on that river is limited.

Now, what have we to do? Simply to store and keep the water which comes down into Humboldt Lake at the various forks of the river—North Fork, Boulder Creek, Little Humboldt, and other sources of the Humboldt, and perhaps in reservoirs along the line of the river itself, where sites have been surveyed—to keep the surplus water there until it is required in June and July, and then let it down the river to be taken out by the irrigators. If efficient measures are adopted for the storage of the water in the storage sites that have already been ascertained, the Humboldt River is capable of reclaiming at least 500,000 acres, and probably even 1,000,000 acres.

A former United States surveyor-general, C. W. Irish, C. E., addressed a letter to the State convention, from which the following excerpts are made:

> In round numbers, the surface of the State can be divided into 50,000 square miles of mountains and mountainous lands, 41,000 square miles of naked deserts and water surface combined, and 21,000 square miles of agricultural lands. Of the last, about 400,000 acres will be found in the foothills and cañons of the mountain ranges, 780,000 acres within easy reach of the water needed for its cultivation, and the remainder, 11,220,000 acres, so situated, or at so great distances from the water needed for its cultivation, as to call for capital aggregated in the hands of incorporated companies for its improvement. * * *
>
> I very much doubt if the State has now 70,000 acres under the plow. It may have more than this quantity of land said to be cultivated, but a large share of it is simply watered to cause a larger growth of the natural grasses found growing upon it. We have an abundant water supply, which I am convinced is fully sufficient to put every acre of our now dry and useless agricultural lands under improvement. * * *
>
> We should foster three classes of wealth-producers—farmers, stock-raisers, and miners—with the accompanying trades and callings needful to the wants of these three leading classes. We must do this, for the reason that our State presents in an abundance the natural resources upon which the classes stated thrive, and, in my opinion, it will paralyze our efforts to prosper the State if we ignore any one of the three classes named.
>
> The agricultural lands should be placed in suitable quantities in the hands of only those who will occupy and improve them, and the water, justly subdivided, should be made an appurtenance of the land it vivifies. The mineral lands should be reserved for the discovery by and use of the miner, who will occupy and develop the metal-bearing veins.
>
> The timber should be placed at the disposal of the miner and farmer, in quantities suitable to their needs, and the mountain ranges should be subdivided by tracing across them the township lines, but not subdividing the townships, setting the same number of corners for the marking of the interior lines of each township as are used to mark out a section, thus rendering it an easy matter to subdivide such surveyed townships. The mountain lands so surveyed should then be sold or leased (with proper reservation of water rights and storage of it in favor of the adjacent farming lands, and also of the minerals and timber which they contain or produce) to those who will take them and properly use them for stock raising or grazing purposes. * * *
>
> It will cost not less than five and a half millions of dollars to survey the mountain lands of Nevada under the system as now practiced by the United States, while by the plan I have proposed it will only cost about three-quarters of a million of dollars.
>
> The cost per township by my plan of surveys, and all other expenses attendant, would be about $650, and such township should be sold to actual users in wholes, halves, and quarters for $1,000 per township.
>
> The sale of all classes of lands I have named to be made only to actual and immediate users, with no alienation of title by the purchaser, until complete improvement of the land sold to him, saving and excepting the timber and grazing lands, which should be required to be put to immediate use. The price of all the lands in Nevada to those who will take and improve them should be reduced much below what it is now. It costs the United States only from 2 to 5 cents an acre to acquire, survey, and sell the lands which have cost the purchaser $1.25 an acre.
>
> I am sure that 780,000 acres of Nevada's lands can be brought under cultivation through individual effort alone at a cost not to exceed that which improved the wild lands of the Mississippi Valley, which was, on an average, $5.65 per acre for fencing, breaking up the sod, planting, and building to fit the claim for an abiding place.
>
> The remainder of Nevada's lands can only, in my opinion, be brought under cultivation through the united work of the organized colonies, or by the aid of capital in the hands of incorporated companies.
>
> The climate and soil of Nevada can produce all of the crops and fruits raised in the United States from Southern California around through Texas and the Southern States north of the Red River of Dakota.

Bulletin 163, United States Census Office (F. H. Newell, special agent), gives the following data as the enumerators' figures for the "census year ending May 31, 1890."

Number of farms	1,341
Number of farms irrigated	1,167
Average size of farms irrigated ....acres..	192
Average annual value of products ....per acre..	$12.92
Irrigated area (total) in acres	224,403

[NOTE.—The area in crops other than forage is estimated at about one-tenth of the whole, or 22,440 acres. It is also estimated that there were 280,000 acres irrigated for pasturage purposes.]

According to these figures, Nevada, with a population of 45,761 (see census returns 1890), would have had of crops other than forage over four-fifths of an acre per capita. With forage crops the irrigable acres would have been within a small fraction of 5 acres for each individual in actual cultivation, while, adding the "alleged" pasturage irrigation, the amount per head would have been over 11 acres.

The following table of grain and other cultivated areas is made from the sworn returns of the several county assessors for the year 1890, as given in the State Surveyor-General's Report for 1889 and 1890:

	Acres.
Churchill	1,018
Douglass	3,474
Elcho	6,961
Esmeralda	232
Eureka	1,427
Humboldt	5,012
Lander	3,048
Lincoln	2,250
Lyon	2,265
Nye	1,574
Ormsby	740
Washoe	3,074
White Pine	1,280
Total	32,355
Orchards (estimated)	5,012
Vines and small fruits (estimated)	9,500
Total cultivated, other than grasses	46,867

Separating all the crops given by the assessors from the hay crop in acres and tons, the following table is the result:

Counties.	Acres inclosed.	Acres cultivated.	Acres in hay.
Churchill	44,225	12,136	8,727
Douglass	30,000	20,000	12,000
Elcho	231,600	54,361	47,400
Esmeralda	6,000	4,000	2,500
Eureka	142,125	19,540	18,000
Humboldt	200,000	5,000	5,000
Lander	60,643	4,500	6,000
Lincoln	11,046	3,831	3,703
Lyon	34,000	8,000	12,480
Nye	16,035	10,132	932
Ormsby	5,016	2,019	200
Story	550	550	800
Washoe	45,637	8,810	18,620
White Pine	15,000	10,000	7,000
Total	641,899	162,879	143,362

The assessor's figures will necessarily prove to be the more correct.

Some explanation is necessary for a clearer understanding of these figures than would be given by a study without knowledge of conditions. In the first place the county assessment returns will give a crop return (other than grass or forage) of over one-third more than the bulletin figures allow. That makes no provision for the orchard, vine, and fruit area. The assessors give the number of trees, vines, etc., and allowing the usual space for each, the acreage is readily obtained. Altogether the total is nearly double the bulletin figures in cultivation other than for forage crops. In the next place the same authority gives as cultivated in all crops a total of 61,585 acres less than the census—very nearly one-third of the alleged area of 224,403. Again, the distinction made in crops is inadmissible in a fair understanding of the process and growth of reclamation from aridity by means of irrigation. Forage crops like alfalfa, timothy, clover, or other grasses, which are cured into hay and sold upon the markets, direct or as cattle, is as much a product of irrigation cultivation as oranges, sugar beets, grain, or any other special product. Area irrigated without planting or working, and simply for pasturage purposes, may be left out of all estimates.

ANSWERS FROM CORRESPONDENTS.

The following data have been compiled from answers received to circulars sent by this office:

LANDER COUNTY.

Battle Mountain (post-office), George W. Crune (September, 1891):

No irrigation systems in neighborhood and little land cultivated; water supply, Humboldt River and other mountain streams fed by the melted snows. Supply copious in spring, but scarce later; storage facilities very much needed; Government aid suggested; has a garden irrigated by an artesian well; water from small streams utilized in spring by settlers by very small ditches; small parcels of land near the mountains thus irrigated. About 25 miles above him on the river three or four dams have been built and ditches taken out, but settlers below have taken the matter into the courts.

WHITE PINE COUNTY.

Cleveland (post-office), A. C. Cleveland (September, 1891):

Neighborhood water supply, mountain streams and springs; capacity about 5,000 inches.
Irrigation works, about 13 miles of ditches of various sizes; no reservoirs or other works of much consequence.
Cost per mile of ditches, about $150 for larger ones.
Average cost per acre for preparing land for cultivation under irrigation, $5.
Average cost per acre for annual maintenance and repairs, about 30 cents.
Area in neighborhood covered by ditches, 4,200 acres (in grass and crops).
Products: Alfalfa, wheat, oats, barley, potatoes, etc.
Average yield per acre, about 2,000 pounds (not less).

CHURCHILL COUNTY.

Stillwater (post-office), Charles Kaiser (September, 1891):

Main water supply: Carson River, fed by snows of the Sierras (river runs for 75 miles through county); about 120 miles of individual ditches; no reservoirs; cost of ditches per mile, about $50; cost of water per acre per annum, about $1.50 (including maintenance and repairs).
Average cost per acre for preparing land for cultivation under irrigation, $10; for grazing, $4.
Area under irrigation at present, about 40,000 acres (water sufficient, with proper storage, to irrigate 150,000 acres).
Area covered by his own system, about 10,000 acres.
Chief products: Wheat, barley, oats, alfalfa, etc., and potatoes.
Average yield per acre: Wheat and barley, 1 ton; alfalfa, 4 tons (two cuttings); wild hay, 1½ tons.

St. Clair (post-office), Lem Allen (September, 1891):

Water supply: Carson River, water scarce in August.

Irrigation works: Three ditches; average length, 3 miles; 6 feet on bottom, 8 feet on top; capacity, about 500 inches each; 3 dams, 4 feet high, from 100 to 140 feet long; 3 head gates; no reservoirs.
Cost per mile of ditches, $60; cost of dams, etc., $200.
Average cost per acre for works, ditches, etc., about $1.50.
Average cost per acre for preparing land for cultivation under irrigation from $5 to $10; for grazing, about 50 cents.
Average cost per acre for maintenance and repairs per annum, about 50 cents
Cost of water supply to user per acre, $1.50 per season; no annual rental
Area under ditch, 2,800 acres; under cultivation, 1,200 acres.
Chief products: Barley, wheat, oats, alfalfa, potatoes, and fruit.
Average value of crop per acre, from $8 to $14.

OREGON.

The entire State lies between the forty-second and forty-sixth parallels of north latitude, and between 116° 40′ and 124° 45′ of longitude west from Greenwich; from north to south the distance is 275 miles, and from east to west nearly 350 miles. It contains 95,274 square miles, and in all 60,976,000 acres of land. The northern boundary line, for two-thirds of its length, is made by the Columbia River; the western boundary line by the Pacific Ocean, and the eastern by the State of Idaho. That portion of the State which may be classified as arid and semiarid lies east of the Cascade Range, a continuation of the Sierra Nevada, which bisects the State from north to south, leaving the western slope and sea plane to occupy one-third thereof. The climate of that one-third is naturally humid and almost as much so as that of the British Isles. Crops, grass, and trees, with the exception of the mountain timber, bear a strong resemblance to the verdant fields of England. East of the Cascades the territory is divided into fourteen counties, the majority of which are very large. The northern portion may be considered as semi-humid in character, being watered by large streams. the Columbia and its tributaries, the Des Chutes, John Days, and Umatilla rivers. The Snake River, turning northward near Boise, Idaho, forms for more than half the State the eastern boundary. The highest ranges of the Idaho panhandle region, with the Blue Mountains in Oregon, make the northeastern section quite a broken country, whose foothills, however, are favorable for the cultivation of fruit. This region will probably develop a considerable supply of underground water both drift and artesian in character.

The southeastern and central portions of eastern Oregon is composed chiefly of moderately elevated plains, admirably adapted at present to pastoral purposes. The western portion of this section is a broken mountainous country, quite arid in character, with a few streams and some mountain lakes, filled by spurs of the Cascade Range, and having a rugged drainage area. The Des Chutes River, running, with its forks, north, is a deep, precipitous stream without much valley land, and the Klamath, in the extreme southwestern section of eastern Oregon, embrace with the Crooked River running east and west the principal water courses of the eastern Cascade region. Malheur and Harney lakes, practically one body of water, though named differently, form the central drainage basin of Harney County. Lake County, farther to the southwest, has a number of similar bodies of water; among them are Albert, Summer, and Warner lakes, in the center; Silver and Goose lakes, to the north and south. They are to a large extent shallow in depth, fed by the broken spurs of the Sierra and Cascade ranges, and considerably alkalized. Klamath, Lake, Harney, Crook, and Grant counties, with a considerable portion of Baker and Malheur counties, form the more arid region of eastern Oregon. Upper and Lower Klamath and Klamath Marsh, in the county of that name, form large bodies of water admirably adapted for storage purposes. The northern portion of Lake County, as well as a considerable part of southwestern

Harney and the southern and western portions of Malheur County, comprise a series of high table-lands, without water, and having a scant supply of grass.

The principal irrigation works now in existence in Oregon are found in Klamath, Baker, Union, and Umatilla counties. Mr. William H. Hall, formerly State engineer of California and ex supervising engineer of the United States Irrigation Survey, has been engaged during the past year as consulting engineer for large irrigation projects. In addition to a small number of works and the acreage they are now prepared to serve, there are, according to Mr. Hall, six large irrigation enterprises under way in eastern Oregon. There are ten or twelve others projected, considered by him to be entirely feasible. The Northern Pacific Railroad Company, the owner of an enormous area of land, a considerable portion of which must be irrigated in order to become valuable, has taken great interest and will sustain some of the projects of which Mr. Hall has been speaking. Along the Snake Valley, upon the Oregon side of the upper part of Malheur and the eastern part of Baker counties, some irrigation is in progress by means of water lifted from the river with pumping machinery. Considerable success has attended these efforts, and it is quite certain that for surface irrigation there is no more economical process than that of lifting from large streams like the Snake and Columbia rivers bodies of water sufficient to fertilize their bench lands. The irrigation engineers of India are strongly in favor, as a matter of economy, of the use of water by the lifting process.

The cattle and sheep raising interests of eastern Oregon, as well as that of mining, remain as yet indifferent to the progress of irrigation. The same apathy prevails in a large degree as that which twenty years ago characterized the few people residing in the San Joaquin Valley. The land for grazing purposes is scarcely worth the Government price; with irrigation it will unquestionably be worth from $40 to $60 per acre. As soon as the water is brought into juxtaposition with the land cultivation begins. Each one of the projects mentioned by Engineer Hall will, according to his estimate, reclaim from 50,000 to 100,000 acres of land, or, in all, 1,250,000 acres. A moderate statement from other sources of the reclaimable land in eastern Oregon places the total at 3,000,000, considerably less, in the judgment of others whose opinions are of value, than the facts warrant. Mr. Hall's estimate for works is of a costly character, involving an outlay of about $12,000,000. Information from the State Chamber of Commerce at Portland estimates that there are approximately 3,000,000 acres of land within the State, located in Wasco, Grant, Umatilla, Baker, and Malheur counties, that could be easily irrigated from the waters of the Snake and Umatilla rivers, Harney Lake, and numerous creeks found there. Mr. S. B. Willey writes:

> I can learn of nothing in the way of any estimate ever having been made of the cost of ditches for irrigating land in any of these sections, but should consider that the cost would not be very great, owing to the large volume of water that could be tapped and the fact that the natural fall of the streams is in the direction of the land required to irrigate. Small patches of land in Umatilla County along the Columbia River which have been irrigated simply by means of hose show a luxuriant growth of grass, trees, and small fruits; peaches, grapes, etc., have grown very abundantly.

Through the Chamber of Commerce also, the following letter from C. E. Foster, C. E., of Baker City, Oregon, has been received:

> Irrigation in Eastern Oregon is progressive; although no comprehensive system for the reclamation of large areas has yet been matured, still individual farmers wherever practicable are extending their ditches to cover larger acreage and distribute water more economically, as their experience has proven that artificial irrigation doubles and trebles the quantity of their crops. As a rule in this vicinity every

farmer utilizes all the water available for irrigation purposes, and the chief trouble lies in the fact that the water supply is limited. As the country fills up with agriculturists the quantity of water for each individual grows less; hence irrigation is made a study by the farmer, to the end that he may so apply the water at his command as to realize the best possible results. It is a conservative estimate to state that 100 miles of ditches have been constructed in Union, Baker, Grant, and Malheur counties during the past year by individual farmers.

As additional evidence of the increasing interest taken in irrigation in eastern Oregon it may be stated that during the past season various companies have been organized for the purpose of constructing reservoirs on an extensive scale and to build canals of sufficient capacity to reclaim many thousand acres of desert lands. One of these companies has located a reservoir site on Powder River in Sumter Valley (Baker County), 20 miles southwesterly from Baker City. This reservoir will cover 1,400 acres of land with an average depth of 30 feet of water. Preliminary surveys of the main canal and distributing branches have been made and the engineers are now in the field. This system when completed will afford irrigation to a large portion of the Powder River Valley with the country immediately east thereof, and is intended to supply water sufficient to reclaim 75,000 acres. Another enterprise of similar nature, having for its object the irrigation of 5,000 acres in and adjacent to Eagle Valley in Union County, has been undertaken, and surveys for the canal are now being made. The water supply for this enterprise is to be furnished by Eagle Creek.

A movement is being made in Umatilla County to utilize the waters of the Umatilla River and reclaim a large tract of land situated near the base of the Blue Mountains. The canal for this purpose will have a carrying capacity of 25,000 inches.

The owners of the Eldorado Ditch, situated in the southern part of Baker and the northern part of Malheur counties, which was originally constructed for mining purposes at a cost of $400,000, have taken the initiative steps to use a portion of their water for irrigation. To this end lands have been bought and located and additional lines of ditch have been surveyed. This scheme will reclaim from 5,000 to 8,000 acres. The Malheur River has been dry at its mouth during the past season because of the various ditches tapping it. The principal ditches taking water from this river are the Nevada Company's ditch, 20 miles long, 2 by 8 feet; the Frohman ditch, 6 miles long, 2 by 6 feet; the McLaughlin ditch, 4 miles long, 2 by 3 feet; the Thompson ditch, 3 miles long, 2 by 4 feet, and the L. F. Company's ditches, one 3 miles and one 14 miles in length; capacity, 2,000 inches.

The Owyhee River has not been utilized to any considerable extent and possesses all the features necessary for an extensive plant for irrigation; large tracts of fine soil lie adjacent to the river and to Snake River, and 50,000 acres could be covered with a canal 25 miles in length.

Reservoirs for the storage of the surplus water of springtime must be constructed in this country before the agricultural capabilities of eastern Oregon are developed; as most of the streams have already been appropriated and the water supply is insufficient, it becomes a matter of necessity that such reservoirs be constructed.

Engineer Hall describes the Powder River Valley irrigation plan as designed to secure the irrigation of 90,000 acres of land. A dam 137 feet high is to be completed across the river, making a back-water storage over an area of 16,000 acres. At least 60,000 acres of the proposed land to be reclaimed is entirely worthless without some such water supply. A contract of $2 per acre as a water rate is being asked by the company engaged in this enterprise. Baker County has, adjacent to Baker City, one irrigation canal served by a storage reservoir, the cost of which is given at $60,000. In the Powder River Valley there are 10 artesian wells reported in operation, 4 of which supply Baker City with water for town and domestic purposes. No details are accessible as to their depth, strata, volume, or pressure. In Klamath County, the southwest section of eastern Oregon, irrigation works are reported, the main canals of which have a length of 32 miles. The cost of these works is stated at $32,000 and the acreage served at 30,000. The source of the water supply is the Upper Klamath Lake. It is estimated that the waters of the Upper and Lower Lakes, so named, can be utilized and so distributed as to serve 200,000 acres. The crops grown on the land irrigated are wheat, rye, oats and barley, alfalfa, potatoes, and timothy grass. During the past season 2,000,000 bushels of grain were raised, being over 60 bushels per acre. The selling value of irrigated land is from $15 to $20 per acre; nonirrigated, the Government price is $1.25.

Umatilla County reports that not less than 300,000 acres, now valuable only for pasturage, could be made to yield, with irrigation, excellent crops. This land, situated in the bench or mesa formations of the river valleys, has already been occupied, farmed, and abandoned, because of the insecurity arising from insufficient rainfall. The sources of water supply in Umatilla County, besides the Columbia River on its northwest border, are the Umatilla River, the Mackay, Burch, Butler, and other creeks. The Blue Range, running from north to south with an east and west trend, forms on the eastern edge of the county a natural water-gathering area, the effect of which is seen in the numerous bored wells that are to be found among the foothills and small valleys thereof. A company has been organized to utilize the Umatilla River supply. It is expected that at least 67,000 acres can be reclaimed thereby. No valuable site for a reservoir is found on the river, and therefore the flow only can be made available. The small streams are, however, all of them capable of being impounded in storage basins, so that the entire supply that now largely sinks into the ground can be, it is claimed, made useful. The area of irrigated land is quite small as yet, small patches along the river being only so served. There are many bored wells in the county, used generally for stock and domestic purposes. No trial of any extent has been made as to fruit. Wheat and other cereals average 25 bushels to the acre, and the yield can easily be doubled by means of irrigation.

Morrow County, with 161,908 arable acres, located to the west of Umatilla, is largely served as to water by means of its phreatic and subirrigation supplies. The irrigation practiced is quite limited, the supply being usually from small creeks. A large number of shallow wells have been bored or dug and the water is generally used for stock and domestic purposes. At Heppner, the county seat, an artesian well is being sunk. Its present depth is 650 feet, but as yet no flow has been obtained. Water was struck with a temperature of 65 degrees, very pure and apparently inexhaustible—evidently a drift or underflow supply that does not rise to the surface. It is proposed to sink a deeper well and, if possible, reach artesian waters.

The following paragraph is from a letter to the Department, sent by Hon. W. H. Bejers, United States surveyor-general of Oregon:

> There is a vast territory of bench lands along the Columbia River, from the Blue Mountains on the east to the Cascades on the west, that might be greatly benefited by irrigation. From the north boundary of Crook County to the south boundary of the State, are many valleys of fine soil; also high plateaus of good agricultural lands which are now only "desert" from the fact that they are not supplied with water. Much of the Crooked River and Ocho valleys are nearly worthless on account of the scarcity of water. The "Desert" between Crooked River and Silver Lake is only so named because no water is found in that region. The same might be said of all the county east and south to the State line. A vast amount of it may never be reclaimed, and yet there are many acres of fine lands, and if there were only enough water a crop could be secured. Around nearly all the lakes in southeastern Oregon are a great number of acres of good level lands, with fine soil, that need to be properly irrigated. Some of these lands are eaten up with alkalies, but about Clear, Summer, Goose, Klamath, Harney, and Warner lakes there are large bodies of good land. There is a small lake some 15 miles east of Warner, in the southeast part of the State that must have nearly two townships of fine land, all worthless now from a lack of irrigation. My idea is that these high lands would require artesian wells, while the low lands in most cases might be irrigated by the waters of the lake. The table lands between the Blue Mountains and the Columbia would also be a fine locality in which to experiment for artesian waters.

Wheat is the staple agricultural product of eastern Oregon. Its quality has made it famous in the grain markets. The yield averages from 25 to 30 bushels per acre, and often exceeds 40 bushels. In 1887 not less than 300,000 tons, or 10,000,000 bushels, were offered for sale. Of this total the country east of the Cascades yielded 200,000 tons. The amount has been largely increased since that date. Irrigation will easily double the products of the same area.

East of the Cascade Range the soil is of a dark loam of great depth, composed of alluvial deposits and decomposed lava overlying a clay subsoil, and rests upon a deep basaltic formation. This soil is peculiarly adapted to wheat-growing. All the mineral salts which are necessary to the perfect growth of the cereals are abundant, reproducing themselves constantly as the gradual processes of decomposition in this soil of volcanic origin proceed. The clods are easily broken by the plow, and the ground quickly crumbles on exposure to the atmosphere. In southeastern Oregon, notably in Malheur and Snake River valleys, the soils are much like those of the northeastern Oregon region, but there is less moisture. Except in a very small proportion of this region, irrigation is necessary to successful agriculture.

The climate east of the Cascades generally gives a temperature higher in summer and lower in winter than that west of the range. The winters, though short, are sometimes severe, and the summers are almost entirely arid. The average amount of rainfall throughout eastern Oregon will not exceed 15 inches per annum. The upper part of the State and the section of the valley of the Columbia River make a funnel by which the influence of the Japanese current is strongly felt, bringing in winter what is known as the "chinook" wind, which greatly modifies the temperature over the larger portion of the eastern section. The thermometer ordinarily indicates 90° as the highest summer temperature, and 10° above zero as the lowest for winter. In the highest valleys, among the mountains, the winters are also short and rather severe. Snow seldom falls before Christmas, and sometimes lies from four to six weeks, but usually disappears in a few days. In the northern and eastern counties spring begins in February with warm, pleasant weather, and lasts until the middle of May. The average temperature is 52°. Autumn weather, in October and November, is generally good; there are often frosts by night, but the days are usually warm and bright. The season is marked by showers, and also by thunderstorms in some localities. The mercury ranges between 55° and 70°. The annual rainfall does not average more than 20 inches, but south of Powder River it is not more than 15 inches, increasing gradually to the north. At Camps Watson and Grant, in the central plateau region, an average of 14 inches per annum is shown. Camp Harney, at a greater elevation, gives less than 9 inches. The Dalles, Wasco County, at 350 feet elevation, gives for a period of thirteen years an average of 21.06 inches; for the summer months, 2.10; for the winter, 13.56. Umatilla County, in the northeastern portion of the State, gives an annual mean of 9.81 inches; 1.66 for the summer months, and 4.78 for the winter ones. Fort Klamath, in the southwest, at an elevation of 4,200 feet, shows a mean annual temperature of 43.2°; for summer, of 57.2°; for winter, of 30.6°. Its precipitation gives a mean annual average of 21.60 inches; for summer, of 1.90; for winter, of 13.72. Lakeview, in the same section, at an elevation of 4,850 feet, gives a mean temperature of 47.1°; for summer, of 64.6°; for winter, of 33.5°. Its records show a precipitation of 18.98 inches annually; for summer, of 3.08; for winter, of 6.79. Linkville, at an elevation of 4,250 feet, presents a mean annual temperature of 48.5°; for summer, of 63.3°; for winter, of 35.3°. Rain and snow fall of 17.85 inches annually; for summer, a fall of 1.87;

for winter, one of 7.77 inches. The southwestern section, then, of eastern Oregon will give in temperature a mean of 45.9°; in precipitation a mean of 19.72 inches, and of elevation 4,525 feet.

La Grande, the county seat of Union County, in the northeastern portion of Oregon, has an elevation of 2,784 feet; its mean precipitation is 24.55; for summer it is 2.66 inches; for winter it is 15.81.

These figures, especially as to the summer and winter precipitation, place eastern Oregon as to climatology in direct relations with the arid region west of the western slopes of the Rocky Mountains, that is, from Utah to the Coast Range. East of the Rockies and within the irrigable valleys, basins, parks, and bench lands thereof, the annual precipitation, divided into three periods of four months each, will give the smallest precipitation for the months of January, February, March, April, and the largest during May, June, July and August. In the growing and ripening months west of the Rockies, the records show an almost exact reversion, the least precipitation being in the four growing months and the heaviest in the first four of the year. By precipitation is meant, of course, measured inches of water. The chief cause of this notable difference is found, in all probability, in the relative severity of the winter of each division. It is one that must be borne in mind when considering irrigation problems.

In volume 4 of the testimony taken by the Senate Special Committee on Irrigation, the following table gives, on the authority of J. W. Steele, the amount of land irrigated and under ditch within the boundaries of eastern Oregon:

Counties.	Acres irrigated.	Acres under ditch.	Counties.	Acres irrigated.	Acres under ditch.
Baker	5,000	10,000	Malheur	40,000	60,000
Crook	8,000	8,000	Morrow	6,000	18,500
Gilliam	3,000	5,000	Umatilla	5,000	7,000
Grant	10,000	10,000	Union	5,000	8,000
Harney	20,000	20,000	Wallowa	7,000	10,000
Klamath	5,000	30,000			
Lake	5,000	5,000	Total	109,000	191,500

This table bears the date of June 27, 1889, and was presented by Director Powell, of the U. S. Geological Survey. More recent investigation establishes the fact that not over 75,000 acres, instead of 191,500, were under ditch in the whole of eastern Oregon, and not over one-half of that acreage was cultivated. A reasonable estimate will increase the area cultivated to date to 45,000 acres, and that under ditch and valuable for irrigation at 100,000 acres. This is a liberal statement.

The Umatilla Valley during 1891 has been the seat of considerable activity. Six companies are operating therein, and disputes have arisen requiring suits to settle the question of priorities. These, however, are understood to be of a friendly character, for the purpose of enabling the larger corporation to settle all controversies, and so enable it to dispose of its bonds. Another suit for the same purpose will decide the constitutionality of recent irrigation legislation and will settle the rights of riparian owners. The humidity of western Oregon renders acceptable therein the English common law on water; in eastern Oregon, however, that of the public control for beneficial uses, as is the case in all arid regions, must control. Pumping for the irrigation of orchards is being extensively practiced along the Columbia River. In the Snake Valley, both in Idaho and eastern Oregon, the current wheels, as they are termed, which have long been in use for lifting water onto the placers for mining purposes, are now being utilized for raising water to be used in irrigation. They are large wooden wheels from 12 to 24 feet in diameter, along the flanges or wings of which are ranged wooden buckets, so hung as to dip and bring up the water to be emptied into a flume or conduit, by which it is conducted into distributing ditches, or in some cases into tanks or reservoirs. The wheels hang in a strong gallows frame, and are moved by the current. It is reported that 500 cubic feet per diem can be lifted with ease. At Baker City and in the valley of Tongue River, the use and extension of irrigation is steadily increasing; on McKay Creek, at Pendleton, the irrigation works are steadily progressing. They are of considerable magnitude. The construction of the reservoir requires comparatively little labor and expense, as three natural walls exist. When the dam is built a lake will be created 22 feet deep and covering an area of 170 acres, with a capacity of 900,000,000 gallons. There will be a supply of water easily sufficient, it is claimed, to irrigate 25,000 acres. The same active workers who direct Boise and Nampa system, in southwest Idaho, are interested in the Pendleton reclamation work. There is good reason to expect the finding in this section of a fair supply of artesian water and a moderate pressure.

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers to circulars received by this office:

HARVEY COUNTY.

Burns (post-office), Mrs. M. E. Dalton (November 22, 1891):

Under cultivation, 160 acres; area "under ditch" in vicinity, 3,000 acres.

Water supply: Silvies River, fed by springs and mountain snows; valley 75 miles long, 50 miles wide; mostly sagebrush land, worthless without irrigation; water sufficient to irrigate all land in valley annually wasted; dam at cañon needed; works (in progress), dam 25 feet from bank to bank; depth of water, 6 feet; headgates and other gates being built, 10; ditches, 6 miles in length, 14 feet wide at top (sloping to bottom); depth, 2 feet.

Flumes (probable cost of), $100.

Cost of ditches per mile, $100.

Cost of maintenance and repairs, 15 cents per acre.

Annual cost of water, 33⅓ cents per acre.

Products: Hay and grain; product per acre, hay, 1½ tons; wheat per acre, 50 bushels; oats and barley, 75 bushels per acre.

KLAMATH COUNTY.

Linkville (post-office), G. W. Smith (October 17, 1891):

Water supply: Big Klamath and Little Klamath lakes (big lake, 37 miles long by 8 miles wide; little lake, 15 miles long by 6 miles wide).

Irrigation works: Two ditches (one from each lake), each about 12 miles long; ditch from big lake carries 1,000 inches water; ditch from little lake about 2,500 inches; one headgate for each ditch; several flumes.

Cost per mile of ditches: Big lake ditch, about $1,000.

Cost of water to user, $4 per inch; about same per acre.

Linkville (post-office), J. T. Henley, president Klamath Falls Irrigation Company:

Source of water supply: Big Klamath Lake, supplied by 3 or 4 small rivers; supply continuous and abundant; "outlet to lake is Link River, which carries about 100,000 inches at low tide."

Irrigation works: Ditch 16 miles in length; width, 12 feet at bottom, 16 feet at top; reservation projected.

Area under ditch, 100,000 acres; under cultivation, 1,200 to 1,500 acres; using water, cost of ditches, etc., per mile, about $1,250.
Average cost per acre for preparing land for cultivation under irrigation, about $7 (in vicinity of this ditch).
Average cost per acre for maintenance and repairs, per acre, about $1.50.
Cost of water supply to user, $4 per miner's inch per season.
Products: Wheat, rye, oats, barley, potatoes, and most hardy vegetables; also alfalfa, timothy, redtop, red clover, and all grasses.

UMATILLA COUNTY.

Pendleton (post-office), secretary Blue Mountain Irrigation and Improvement Company (September, 1891):

Source of water supply: McKay Creek (stream has flow of 45 cubic feet per second; drainage area, 135,000 acres, all wooded).
Irrigation works (construction commenced September 26, 1891): 58 miles ditches, 15 feet on bottom, 27 feet top (main ditch); one reservoir, area 170 acres; average depth, 22 feet on 50-foot level; dam 280 feet on bottom, 520 feet on top (length); five headgates (it is also proposed to supply city for domestic uses).
Cost per mile, ditches, $2,800 (estimated); cost of dam, $70,000 (estimated).
Annual rental cost of water per acre, $3.
Area under ditch, 30,000 acres.
Area under cultivation, 10,000 acres.

Pendleton (post-office), E. J. Horton, McKay Creek Irrigation Company (September 23, 1891):

Water supply: McKay Creek (a mountain stream with capacity of about 2,000 miner's inches).
Irrigation works: Six and one-fourth miles ditch, 5 feet at bottom, 8 feet at top; two dams 5 feet high, 60 feet long; two headgates; no reservoirs.
Cost per mile of works, $300; average cost per acre, $3.
Average cost per acre for preparing land for cultivation under irrigation, about $5; for annual maintenance and repairs, 25 cents.
Cost of water supply to user per acre, $1; annual rental, $3.
Area under ditch, 1,500 acres; under cultivation, none.
Products of neighborhood under irrigation: Wheat, corn, alfalfa, timothy, fruits, and vegetables of temperate climate.
Average yield per acre; Wheat, 50 bushels; corn, 60 bushels; alfalfa, 10 tons; timothy, 4 tons; beets or carrots, 60 tons.

WALLOWA COUNTY.

Wallowa (post-office), J. F. Johnson:

Source of water supply: Wallowa River, average width, about 75 feet; depth, 18 inches; has fall of 100 feet per mile; banks about 3 feet high.
Irrigation works: About 1 mile of ditch, 6 feet at top, 3 feet bottom; brush dams (no reservoirs).
Cost per mile of ditches, $50; cost of brush dam, $50, complete.
Average cost per acre of works, ditches, etc., 50 cents.
Cost per acre for annual maintenance and repairs, about 5 cents.
Area under ditch, 800 acres; under cultivation, 200 acres; 600 acres in grass, hay, timothy, redtop, clover, or native grasses; 200 acres in wheat, oats, and rye.
Yield of products per acre: Wheat, 30 bushels; oats, 50 bushels; rye, 2 tons; timothy, 2½ tons; redtop, 3 tons.

UTAH.

The chain of mountain ranges known as the Wasatch extend from about the center of the northern boundary to the extreme southwest corner, where they leave the Territory. Near the latitude of Salt Lake City the Uintah, a more lofty and rugged range than even the Wasatch, starts off about due east. From this range, again, in the latitude of Utah Lake, and 40 miles east thereof, the Coal Range extends in a line parallel with the Wasatch for about 160 miles, until near Panguitch Lake, where the broad rolling summits of the Coal Range merge into the more precipitous peaks of the Wasatch. The Uintah, the Coal Range, and the southwestern extension of the Wasatch wall, in that portion of Utah originally included in the Great Basin, form the series of mountains which make the central Utah divide and control the drainage areas of the Territory. North of the junction with the Coal Range, the Wasatch Range forms no part of the rim of the Great Basin, although its lofty peaks gather no small portion of the water needed to reclaim the Great Salt Basin.

The bulk of the population and cultivation in Utah is centered around Great Salt Lake, in the counties of Cache, Boxelder, Weber, Davis, Salt Lake, Utah, and Tooele, which form that portion of the basin at present extensively irrigated.

The Jordan (considering the Provo River as its head) Weber, and Bear rivers, are now the principal sources of irrigation. They rise near together in the Uintah Mountains, pierce the Wasatch Range at widely separated points, and empty into Great Salt Lake, contributing the majority of its visible inflow. But besides the drainage of these three rivers, from the Escalante Desert in the extreme south to the northern boundary every drop of water that falls on the high surrounding mountains drains through the salinas and desert plains toward the Great Salt Lake. The heavy precipitation upon the Coal Range and the Wasatches pours in torrents into the bowl of the Great Basin, quickly sinks into the deep wash soil and disappears from sight. As we approach the lowest depression, known as the Great Salt Lake Desert, all signs of water are lost. Therefore, dividing Utah into two great parts, it will be seen that the eastern and southeastern sections drain through the Rio Colorado system to the Gulf of California, while the western and northern portions have no apparent outlet. In the former, no matter how intricate the meanderings, the streams rising on the eastern flanks of the ranges named contribute a portion of their flow to the great Colorado River, while on the other side of the divide not a single stream carries its flood to the sea, and with four exceptions, viz, the Jordan, Weber, Bear, and Sevier rivers, none flow more than a few miles beyond the base of the mountains. The summits of the surrounding peaks are usually covered with snow and the water precipitated therefrom must find its final visible resting place in Great Salt Lake, the remnant of that vast geological lake, known as the Great Basin.

A very important factor in Utah irrigation would be a settlement of questions connected with the precipitation of the western flanks of the Wasatch Range. These valley lands are more accessible to market than the balance of Utah, and when we consider that one cubic foot of water per second or 646,520 gallons per day, flowing continuously during the irrigation season will irrigate an average of 100 acres of land, it becomes of the utmost value to comprehend the source of supply; and in this connection the experience and knowledge of H. L. A. Culmer, editor of the Salt Lake Journal of Commerce, is of material value:

> I believe our present water supply in Salt Lake Valley, and in similar tracts, could be doubled from sources that are now invisible—at least doubled, and certainly along the western flank of the Wasatch Mountains, and in many of their valleys I know that there is an abundance of water to be had, which if developed is sufficient to cultivate every acre. I want to say this, however, that seeing as years go by, that so much more is accomplished than was once thought possible, it is difficult to estimate the future possibilities. Such an estimate would sound Utopian. This statement only includes what may be done from water in sight and the known phreatic supply. I have not considered the limit of irrigation by storage of artesian and surface flowing water to have been reached; on the contrary I believe the desert portion of Utah will become more and more circumscribed, and, perhaps, some day be wiped out from these supplies as the principal source.
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> Speaking on the question of storage I may say that I am very familiar with the Wasatch Mountains, and I know that near the heads of all these cañons there are natural reservoirs. In the Wasatch Mountains, within 20 miles of Salt Lake City, nearly every cañon has at its head an Alpine lake varying in size from a few hundred yards to a mile and a half across. These have evidently been formed by glacial moraines damming up the cañon, making a stronger reservoir than human hands can construct, and larger too. Many of these are very deep, and their outlets are the initial points for the cañon streams. A great deal could be done by heightening these natural dams and thereby increasing the capacity of the natural reservoir. I believe they could be made to hold twice their present capacity. Any attempt to create reservoirs in the cañons other than at these points would be puny in comparison.
>
> It must not be forgotten that at these points of natural storage the evaporation is at a minimum on account of the altitude. There are many others of these alpine lake sites which are now dry, having given way or been worn through at some points. A little work would make them as good reservoirs as those remaining.
>
> My first statement as to the possibilities of reclamation of arid land was made without taking these natural reservoirs into account. Referring to the ultimate reclamation of the desert lands of Utah, I think it will be accomplished primarily by means of the development of water by artesian and driven wells, which will permit the cultivation of limited tracts whereon these wells are secured. Alfalfa and other deep-root crops will be planted at such points, and, in my opinion, will exert a capilary influence on the earth to a depth great enough to reach the water-bearing stratum. This vegetation will also shade the earth and perhaps have a local effect in preventing the drying of the soil, and effecting a change on the lower strata of the atmosphere. As an example of this effect I would refer to the western half of the Salt Lake Valley in the neighborhood of Salt Lake City, which a few years ago was considered worthless for agricultural purposes, because the first attempts at farming were extremely unsatisfactory and disappointing—the ground seemed to require so much moisture, and the crops literally burned up. Until recent years it was considered a desert country and it was not expected that it would ever be peopled. Now, that is what I would call the eastern flank of the Oquirrhs in the Salt Lake Valley. As land, however poor, in the immediate neighborhood of the city is higher priced, the people made extra struggles to secure a living from this arid district. They planted alfalfa in large tracts, and this not only redeemed the quality of the land, but seemed to have made the whole district more moist; and when water was found to be obtainable by means of driven wells, each of which would furnish sufficient water for the cultivation of a tract of 5 acres, the land became valuable, is now largely settled, and is looked upon as a productive region many miles in extent.
>
> Artesian wells in Salt Lake Valley were first used for irrigation about seven years ago, and since that time have increased the area of cultivation from 25 to 35 per cent. It is to be remembered, however, that in the large area of agricultural land in Utah, only a limited portion has yet tried to develop artesian water.
>
> In Emigration Cañon, within 4 miles of Temple Block, the city corporation took the cañon stream and flumed it for a short distance so as not to interfere with its flow by subsequent work. At the point flumed it was estimated that an underground

supply could be developed, and the city dug a trench about 100 feet long and 40 feet deep, projecting the sides with plank with open joints strongly braced. The trench was filled 30 feet deep, and this new supply is drawn off through a 12-inch iron pipe to the city at the rate of 1,250,000 gallons a day. Within 100 feet of this source another long open trench was dug which yields 1,000,000 gallons per day, and this supply is wholly supplementary to that which formerly made the cañon stream. This water is used for city purposes, but it seems to me a big hint to all agriculturists.

In Provo Valley and Krammer Valley I think the same amount of water supply can be obtained. I am also satisfied that every acre of land in the Duchesne Valley can be cultivated from a similar source, and all the arable lands from Strawberry Valley to Book Cliffs could be reclaimed, and the San Pete Valley, also. The Cache Valley, also, has enough of water. All the eastern side of Box Elder Valley, probably Rush Valley, and most likely Fowl Valley can be reclaimed. Sevier Valley is also capable of reclamation, although there nothing has been done.

A belt of extremely rich country, 25 to 75 miles wide, almost the entire length of the Territory, may get sufficient water from the western flank of the Wasatch Range, and can be reclaimed. Every acre that is not watered in the regions named I believe could be from the surface and underflow of the mountains. There are also many valleys in the middle and southeastern part of the Territory which are not sufficiently watered, but which could be with more or less work.

These statements are made on intimate knowledge of this Territory, gained from personal observation and conversation with hundreds of farmers from the regions named.

If you will take the Emigration Cañon work as a basis you will see that I am not overestimating the areas.

I feel now that it would be better to go for the underground supply. It is the quickest method. While there have been very few thoughtful attempts to develop the underground supplies, I know of some instances that have been very successful; but the point I would emphasize is that as a general proposition (and they always have exceptions), a cañon will yield a large supply of water all the year round; at the lowest stage the smallest will yield 1,000,000 gallons daily. Sometimes you will find a dry cañon and one right adjoining full of water. It seems that the water is diverted in some cases from the cañons. I know of many cañons that have within a few miles of the base copious springs, which flow a short distance and sink. They are evidently the natural outpouring of the water after it has gone underground at high altitudes. This underflow could, unquestionably, be tapped, and if reached at bed rock could be brought down to irrigate the bench lands which are very fertile. I am of course speaking of cañons of the Wasatch Range, which are unique in that they have no parallel range of foothills.

On the western flanks the precipitation that falls on the summits sinks into the earth as there are no rivers to carry off the waters of the rain and snow. The drainage therefore must be towards the cañon, as the water would naturally follow the mountain lines till it finds a place with more or less appearance of a channel. I think some of the driest cañons that abut on this valley have at their heads the greatest amount of snow, and are consequently drainage troughs of that vast amount of water. Take for instance the cañon next south of Little Cottonwood Cañon—little or no water goes over the surface and if any goes underground it is wasted, yet at the head of that cañon is an enormous snow basin. The snow lies there always to the depth of many feet; where the water goes to we do not know, but in all probability it follows down the course of the cañon. These cañons are filled with detritus into which the water, that you would naturally expect to flow on the surface, disappears. I feel sure that an inclined tunnel would be sure to find an immense amount of water in all the cañons. I feel satisfied that there is more water beneath the surface than above. About 17 miles south of Provo is one of these dry cañons, called Springville Cañon, very rocky, precipitous, and dry. It looks as if it should yield a copious stream. It is, however, dry while out in the valley is a stream that emerges right from the bank. In other words, through the underflow gravity a considerable stream makes its appearance. When the emerging flow soon becomes a stream, you feel that there is the point where the water line reaches an impervious stratum, and by it is forced to the surface. The same phenomenon is repeated a number of times along the base of the range. Right along in the mountains east of Utah Lake there is unquestionably an abundance of water of which I have already spoken. It also suggests itself to me that under the surface of both Utah Lake and Great Salt Lake, there emerge many heavy streams of fresh water. I do not think these lakes are by any means supplied by the water we see going into them.

Now, take the range here at Pleasant Grove, the mountain is very steep and high, with an almost perpendicular rift; there is no watershed, but a heavy stream comes down. The conditions seem to be reversed, but there is no doubt that this water comes from the other side of the range, miles away, right through the mountain. The line of the summit is just like a man's knuckles, and the summit is between 3,000 and 4,000 feet above the stream. Yet that water comes right through that mountain and out into the valley. Further south than Utah Lake, on the line of the Union Pacific Railway, in the Sevier Valley, in Midland County, in the neighborhood of Deseret, I believe that water can be developed here by the artesian process. But the further you get from the range the deeper you will have to go.

My experience is that no man can take it upon himself to say that there is any tract that can not be cultivated. We have done so much in reclaiming the desert that it is hard to say that any tract can not be reclaimed.

When the underground water is developed and all possible storage availed of I feel certain that the small acreage now called "reclaimable" will be greatly increased. Suppose we bring water from the mountains and irrigate the first bench, and run a channel along its base, we get water enough from seepage to irrigate another tract. The topography offers us the opportunity to utilize water over and over again.

On the benches we come to hardpan at about two feet. This land is, however, on a heavy slope and drains itself. Then below that you generally find another stratum with water. This hardpan is calcareous in character. It is a gravel that has become saturated with running water and puddled. Away from the benches in the valley bottom you generally find a wash, but it is very hard to predict the nature of the substratum; sometimes you find 20 feet of pebbles.

In planting trees on the benches you have to penetrate the hardpan if you wish the trees to thrive. The highest bench does not seem to be the best. There is a middle mesa, or bench—the first bench as we call it—that is the best land in the valley. The next bench is very gravelly, but is suitable for some crops.

As to crops to be raised by irrigation in Utah, I should put wheat and potatoes first, and alfalfa is among the very best. We have had yields of 4 tons of grapes to the acre, and 1,200 bushels of carrots per care. We took the American Agriculturist prizes for wheat, and one of the prizes for the best yield of potatoes. The western flank of the Wasatch comes in for the glory of fruit-raising. In Cache Valley they raise some fruits, but can not compete with us. In the Sevier Valley they try to raise figs, but have not made much of a success. They seem to be cut off from the effect of the California climate by the range. On the Virgin River they can raise oranges. The sugar beet here grows to a great size. We show a constant increase in the annual area of cultivation.

The Government should begin by a very thorough investigation and report upon the whole region to find out the controlling facts. The people living here have demonstrated that irrigation means high cultivation; that we can make an acre of land yield more than an Eastern farmer does. When we get water for our land we are not subject to the caprice of the climate. Forty acres here will support a family as well as 160 acres in Missouri and Illinois, and the Western family will be better supported. In this Territory 8 and 10 acres in staple crops support families. It gives them enough to eat and enough to wear and a sufficient education. My brother told me that for every day's work he put on a 40-acre farm he got $10 a day in return, year in and year out.

Mr. Doremus, city engineer of Salt Lake City, also presents interesting data. He says:

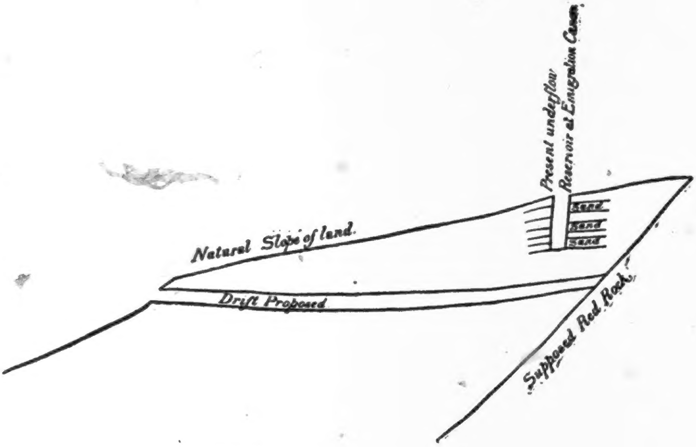
In this valley, in the older irrigated regions, the subsoil will be cemented so hard that a plow can not penetrate it.

At the head of First South street is an excavation made for the city supply. They turned Parley's Creek into the trench and it ran a week without a drop coming to the surface below its line. In constructing sewers and laying water pipes the city engineers find a great deal of trouble from water running under the city with quite a velocity, moving at such a rate that it will wash out cement from the joints of pipes. The water standing in the trenches, roiled and muddy from the operations of the workmen, will clear thoroughly during the noon hour.

At the head of Cottonwood Cañon there are ample facilities for storing water, because there it is a bed of hard granite free from fissures. At the head of Big Cottonwood there are sixteen natural lakes; but probably not more than three or four out of the sixteen would afford means of storing water. Of course, storage would bring up the complicated question of division with the present ditches. This stored water could of course be flumed or taken through another channel.

Irrigation affects the artesian wells and other earth supplies more than the local rainfall. This is shown by the fact that just as soon as irrigation begins the flow of the wells is increased. There is most probably a fissure of geologic fault surrounding the Salt Lake artesian basin. No water comes direct from the mountains into the basin. Often if a man sinks a well a very little lower than one of his neighbors this older and shallower well will cease to flow.

The data furnished by Mr. Culmer as to work at Emigration Cañon is correct. In fact, the experiment has been so successful that there is now proposed a bedrock drift at that point.



Underflow works, Emigration Cañon.

This bedrock drift had not been located but it was confidently expected to afford unlimited supplies of water.

The recent returns to the committee on statistics of the Irrigation Congress which met September 15, 1891, at Salt Lake City show an average waste of 70 per cent of the water used. During the season of 1890, 333,404 acres were actually watered. It is therefore certain that twice that area or 665,808 acres might have been irrigated with the same amount of water had reasonable economy been exercised in distribution and application. Less than one-third of the water actually used under proper conditions would have produced the harvest of 1890. During the same season there were under ditch 735,226 acres. Assuming that the same proportions would apply to the acreage commanded by the canals it is plain that the present appropriation of water in Utah will irrigate all but 833,548 acres of the total estimated area of 2,304,000 acres in Utah. The water in sight and available in Utah is not by any means all appropriated, there being numerous areas large and small in the territory that have sufficient water, but no population or market for its utilization. With due regard to the assertion made on the authority of an official engineer, that only 263,000 acres were irrigated in Utah in 1890, and that that area is about the utmost that can be cultivated without recourse to high mountain storage, the office of irrigation inquiry believes from data in its possession as a reasonable proposition that there is water sufficient, with economic use, to irrigate every acre in Utah upon which it can be made to flow.

This problem is threefold:

(*a*) The economic use by the best known methods of the present surface supply.

(*b*) The development of the immense seepage that flows underground through the cañons and the valleys, and which will continue with or without storage.

(*c*) Storage by dams through the utilization of high altitude lakes, formed in the glacial moraines at favorable spots both in the cañons and on the plateaus.

In considering the future development of irrigation in Utah it must be remembered that the inflow of Great Salt Lake is 7,500 cubic feet per second, sufficient without storage to irrigate 750,000 acres of land. Only a fraction of this amount, however, is at present cultivated. The water is carried to segregated tracts of land without regard to its economical use, the ditches crossing and recrossing and carrying the water down from the bench lands to irrigate the bottoms, paying no regard whatever to the advantages of the local topography. The great bar to future development is that the water rights as now held do not serve the most available land, although a proper diversion of the water in sight will many times increase the irrigable area. A ditch that takes out of the stream 50 cubic feet per second and only delivers 15 or 20 feet to the land is a hindrance to true progress. The owners of water rights must come to some agreement by which larger and more modern canals may be constructed, allowing the diversion of water to the land most available without long stretches of useless main ditch. The acquirement in any neighborhood by an association of the irrigators of all the water rights and sources and a transfer and relation of every right to its proper and nearest source would relieve the art of many of the uncertainties and hardships attendant on the present wasteful system. A much less number of large canals with a minimum of seepage and evaporation would discharge more water for actual use than is now brought to the land by the multitude of small ditches. Now the early settlers or owners of the "prior rights" claim the first exclusive use of water; the surplus is then allowed to those holding secondary rights, and by the time the third or fourth appropriator or new settler is reached there is no water. Useless seepage and evaporation have absorbed 70 per cent of the water taken in at the head gate, and the prior appropriators actuated by natural selfishness have disposed of the remaining 30 per cent. Under this system economy is impossible. The tracts irrigated often bear no economic relation to the source of supply, and the maze of crude supply ditches were constructed to carry as much water as possible to each particular tract, without regard to the fact that the same appropriation in many instances would serve much more land at a point nearer the head gate. One farmer besides a "prior right" may own secondary, third, and even fourth rights in the same ditch, according to the date of first cultivation of different tracts of his land. Primary rights are often not determined with precision, and with all this complication the wonder is that disputes are not more numerous.

Many cures have been suggested for all these evils, most of them requiring the outlay of vast sums of private or municipal capital; but it must be apparent that any benefit to be lasting must as a basis seek the improvement of the present system. False economy must be eradicated, bad construction replaced by good, and above all the irrigators must be informed of right methods. In Utah a small army of men, with prodigal expenditure of labor and water, have reclaimed a small portion of its great arid area, and at the present time high altitude storage of storm water would only intensify the evil, because it would now have the sole effect of giving more water to be wasted in the proportion of 7 cubic feet per second for every 3 applied to the land.

This strong presentation of the irrigation status of Utah is made in a spirit of absolute fairness. Census Bulletin No. 35, entitled "Irrigation in Utah," after a special plea for the necessities of mountain storage, says:

> Owing to the difficulties and uncertainties concerning the supply and distribution of water, many farmers in the northern counties have gone to the extreme of declaring that dry farming is preferable wherever it is possible. Cereals can be raised to a greater profit than by irrigation, although the yield per acre is less.

Intimate personal knowledge and a voluminous correspondence has failed to reveal to the office of irrigation inquiry a single farmer who prefers dry farming to that by irrigation. Upon the very face of the case every drop of water applied to the ripening crop means additional profit to the farmer. If the land has a water right the additional annual expense in Utah is 91 cents per acre for water; if water is not worth this amount then irrigation is a failure. The statement is only noticed because of its connection with many others, all tending to cast the shadow of doubt on present and possible sources of supply. The primary fault in Utah is that the "water in sight" is misapplied; that is, it is directed to certain tracts, not on account of accessibility to the source of supply, but because the owner desired a "prior right" to water, no matter how far he had to go to get it; and the water is consequently wasted. The correction of this evil can only be accomplished by Utah irrigators through proper legislation.

To exhibit some of the past and present physical and economic conditions that environ the irrigator in Utah and influence his actions, the following condensed interviews between prominent local irrigators and the special agent are herewith presented:

Mr. E. G. Wooley, bishop in the Mormon Church, came to Utah in 1850, and like the balance of the Mormons knew nothing about irrigation, as they all came directly from humid regions.

> "The Pioneers" came into the valley in July, 1847. The advance company drifted right down upon the site of Salt Lake, coming through Emigration Cañon.
>
> They went to work the first day, ran a plowed ditch out of City Creek, and started the water out on the ground, and planted some potatoes the same day. That was the first irrigation.
>
> In planting corn we adopted the methods of plowing while the ground is moist in the spring, and then when the time for irrigation came we would open a deep furrow at the head of the field and let the water down shallow furrows between the rows.
>
> In making a settlement we always locate the town on the higher and dry land, and the people live in the community.
>
> Mount Wooley has a large dam situated about 4 miles east of Washington, in Washington County, and about 8 miles east of St. George on the Virgin River. It was first built of rock, dirt, and some brush. Some three years ago we built a dam by driving spiles down and filling in with brush and dirt; but the river is subject to very heavy floods and is full of quicksands, and about a year and a half ago this dam was washed out. Though discouraged, the people decided to make another effort; so they went up the river where the sides are solid rock and low on one side, and they cut a spillway on the north side. The spill is 100 feet in width. We then went to work and built a tight dam across the river, throwing the water through this rock spill, which saves all chance of too great a rise in the river. In putting this new dam in it was calculated that by building a ditch costing about $20,000 they can irrigate 1,000 acres of land. The dam will also cost $20,000. It goes right round the base of the cliff in the solid rock. Where the water is taken out into the ditch the river is dry, but 100 feet below the dam the water begins to seep back, and gradually fills, so that as much water is flowing below our tight dam now as before the dam was built.
>
> At La Verken we have taken out another ditch and tunnel, about 4 or 5 miles south of Toqueville and we irrigated about 800 acres then. In this case we went up

to the gorge of the cañon and put in a temporary dam, and brought the water right out under a rocky cliff; then tunneled through a ridge for about 800 feet, and brought the water out on the bench or mesa land 150 feet above the river bed. This then irrigates 800 acres devoted to semitropical fruits. We can not raise oranges, but grapes, prunes, apricots, pears, etc.

We do not use now in any of the older settlements one-fourth the water that was necessary when the land was first irrigated.

Mr. Frank L. Hines, well driver, Salt Lake City, has been in Utah Territory twenty years, and has resided steadily within 20 miles of Salt Lake City for eighteen years. He states that:

The artesian basin embraces the whole of Salt Lake Valley. In North Salt Lake addition within the city limits, I sunk a well on October 14, 1888, and only had sulphur water at 280 feet. We found there was water but no flow. The strata are: bowlders right in the grass roots for 100 feet, gravel 50 feet, sand 45 feet, hard pan 46, and cemented bowlders for 152 feet. We struck hot sulphur water at 162 feet, and found it in loose gravel in the cement. This well is north from the center of the city 3 miles, straight out Second street west.

E. B. Wicks, Poplar Grove, has a well 3 miles west and south of city, in sec. 1, R 1 S., T. 1 W. The stratum bored was as follows:

	Feet.
Sand and clay	40
Quicksand	120
Clay	4
Sand	100
Clay	3
Sand	120
Hard pan	6
Total	393

Water is found in coarse gravel. Out of this well wood, sheep, and rabbit excrements were taken at 325 feet. It yields 125 gallons per minute by 5-inch pipe.

The Burlington Syndicate well is located on sec. 1, R. 1 S., T. 1 W. The drill passed through—

Surface clay and sand, 6 feet.
Quicksand clean down.
At 160 feet, small flow, about 10 gallons per minute.
At 185 feet, small flow, about 10 gallons per minute.
At 325 feet, small flow, about 50 gallons per minute.
At 452 feet, small flow, about 75 gallons per minute.

Flows through a 4-inch pipe.

City well, No. 1, in Liberty Park, on sec. 1, R. 1 E., T. 1 S. Its strata is as follows (8-inch pipe):

	Feet.
Loose gravel	60
Cemented bowlders	40
Clay	16
Total	116

Water in coarse gravel, 212 gallons per minute.

City well, No. 2, in Liberty Park, with 8-inch pipe, shows:

	Feet.
Gravel and loose shale in alternate layers	130
Cemented bowlders	70
Loose gravel	66
Clay	6
Total	272

Water flows 350 gallons per minute.

City well, No. 3, in Liberty Park, has an 8-inch pipe.

	Feet.
Gravel, shale, red sand, and clay, alternate layers	375
Hard cemented gravel	175
Total	550

Water in coarse loose gravel, 500 gallons per minute. Wood was cut through at 500 feet; it must be from a log a foot or more in diameter. Shells came up with the water. Wood looked as if it had been charred by fire. These three wells are within 70 feet of each other in a line running north and south.

City well, No. 4, in Liberty Park, with 8-inch pipe. Strata same as No. 3; that is—

	Feet.
Gravel, shale, red sand, clay, in alternate layers to	325
Water-bearing sand	380
Thin clay to	400
Total	1,105

With water in coarse gravel. This well is 60 feet from No. 3 and flows 350 gallons.

City well, No. 5, in Liberty Park.

	Feet.
Loose gravel to	110
Clay	15

Good water, with sufficient pressure to take it up to tank 15 feet above surface at the rate of 150 gallons per minute. It flowed 4¼ inches above 8-inch pipe at the rate of 700 gallons. This well is about 550 feet north and west from No. 1.

Perkins Addition well is about a mile from No. 5 well.

Soil and clay 8 feet. From that point down to 120 feet it is cement. It has gone no farther, but the bore is still in the hole. In this same field there are twelve other 2-inch wells, all the way from 26 to 250 feet, and all flowing at an average of 15 gallons per minute.

It is mere opinion, of course, but it is the result of nearly twenty-one years' experience, that if a well is sunk to bedrock so as to get the underflow of Emigration Cañon and Parleys Cañon, a flow of 2,000 gallons per minute might be secured. The same is true of all the other cañons.

There is an immense amount of water flowing into the Salt Lake Basin from the cañons. This is plain to anyone knowing the topography of these mountains. Take Parleys Park, at an elevation of 3,300 feet above sea—a great mountain meadow—which is full of water; 3 feet from the surface it can be obtained in large quantities. Then there is Bonanza Lake, 10,000 feet above sea, which has no visible outlet. Then later the mining tunnels show a great deal of water, as for instance at the Ontario, where the vein is in the contact between the quartzite and porphyry, one tunnel is 600 feet and another 1,000 feet. The Anchor mine has a tunnel in there of 1,300 feet, the Alliance another of 1,800, all of which discharge large quantities of water into this meadow called Parleys Park. To tap this immense supply, say at a point near Park City, would require a tunnel 30 miles, but large supplies coming down in the underflow of the cañons from such sources may be developed at little expense near their mouths. These meadows, or mountain sources, are also the principal feeders of the artesian basin.

Sandy well, at the Mingo smelter, is situated in the wash at the mouth of Little Cottonwood, and sinks 1,485 feet into the cañon wash all the way down. This well is sunk on top of a hill, and where the drill starts is 500 feet above Salt Lake. At about 300 feet deep we struck the first flow.

Mr. Hines has three ranches, two of them irrigated from artesian wells. One ranch is 80 acres, watered by five wells running from 1¼-inch bore to 6 inches. He irrigates 17 acres of potatoes from 2-inch wells flowing combined about 120 gallons per minute, leaving a large surplus of water which he proposes to put on other crops. The water is caught in a reservoir about 1 acre in extent, and 4 feet deep, and from that distributed to the crop.

Col. John R. Winder, of the Bishop's office, Salt Lake City, stated that he came to Utah in 1853. The first irrigation was done from City Creek. The natural flow of the creek was utilized and the water was taken out in laterals over the soil from the sides of the stream. The first ditches were called Kenedy's ditch and Winder's ditch, and were small ditches about 4 or 5 feet wide and 18 inches deep. They were taken from Parleys Cañon. Emigration ditch, of about the same size, was constructed very shortly after. They were all made about 1848.

The Kenedy and Winder ditches are now about 10 feet wide and 18 inches deep; they irrigate about 3,000 acres.

In the beginning we used to have to irrigate wheat to get it up out of the ground, now two irrigations will mature the crop, and the lower land has the seepage from the irrigation of the bench lands. They irrigate only on the high bench lands now as the bottoms are full of water.

The first large canal that was built was the Big Cottonwood. It was built for the purpose of carrying rock to our works, but it was afterwards used for irrigation. It has a fall of 20 inches to the mile, is 20 feet wide on bottom and is 3 feet deep. This canal is on the east side of the Jordán, and it has been merged into what is called the Salt Lake City Canal.

The next canal was the North Jordan, which irrigated the land west of the river. The next was the South Jordan, which goes higher up and takes a better volume of water. The next is the Utah and Salt Lake Canal. These three lie one above the other.

In the vicinity of the city the whole plateau was laid out in 5 and 10 acre lots, but as you went down further into the country the farms would increase in size up to 20, 25, and 30 acres, and sometimes more.

Each canal has a board of directors and they appoint officers. They have one or more superintendents, as the case may be. These superintendents make an estimate of the amount of work they will have to do during the year, and levy an assessment on the stock at so much per share. The shares of stock represent an acre of land and water to irrigate it.

Col. Wilder sunk the first artesian well in the valley. It is a 6-inch bore down 78 feet, with a flow of about 75 gallons per minute. He also drove a second well near the first. When the second was down to the 78-foot level the water in the first stopped. The second well was driven 2 feet further and the water returned to the first well.

Jesse W. Fox (Mormon), ex-surveyor-general of the Territory, stated that—

They commenced irrigation in this valley by leading the water from the main stream above the farming plane to the land. They were taken out on both sides of the stream at intervals convenient for irrigation. At first these were plow furrows and shallow dry ditches. When I came here the irrigation was mostly confined to Salt Lake and Davies counties, and did not exceed 14,000 or 15,000 acres.

The first large canal was taken out in 1870-'71-'72, called the South Jordan. It has been since enlarged and extended. It was originally 6 feet on bottom, 2 feet deep, and 32 inches fall per mile. Its present size is 15 feet on the bottom and 4½ feet deep, and 32 inches fall per mile.

The next was the Utah and Salt Lake Canal, on the west side of the Jordan. The calculation was to set slack water back to Utah Lake, making that lake a reservoir. That canal is 20 feet wide on bottom, and carries 4 to 4½ feet of water in the banks.

The next is the North Jordan Canal, which was located about 1872. It is 12 feet wide on bottom, and carries 4½ feet of water. These three canals are on the west side of the river Jordan, watering the land from the river to the mountain range. On the east side is the Draper Canal, located in 1873, which is 15 feet bottom width. These canals are all 1 to 1 and 1 to 1½ slope.

The irrigation of Salt Lake City was from City Creek, but we have now appropriated the waters of this creek for city purposes, and have constructed a canal from the Jordan River to supply the irrigation formerly had from City Creek. That canal was located in 1880. It is called the Jordan and Salt Lake City Canal. It is 20 feet on bottom, 4½ feet deep.

These are the principal canals, but there are others taken out from Red Butte, Cañon Creek, Mill Creek, Big and Little Cottonwood. The canals named were the first located in Utah.

The duty of water in this Territory has increased at least 30 per cent, without considering the lands moistened by seepage.

Of the canals named, the first five were incorporated, having a capital stock, which stock was principally paid for in labor, only a few paying in money. A share of stock represents water for an acre of land.

H. S. Josephs, C. E., Salt Lake City, stated that—

In NW. ¼, sec. 23, T. 2 N., R. 1 W., is a bore 580 feet deep, and no water. In section 22, same range and township, there is a fine well, having about 60 gallons flow. In section 14 there is another, 175 feet deep, that gives about 15 gallons per minute. This is sulphur water. In the same section there is another well, 175 feet deep, furnishing perfectly pure water. This well is in the northwest corner of the section. On the north line of the same section, about half a mile from the last well, there is another that goes down 400 feet, but water has been struck.

In section 11, a little to the north of the center line, there is a well which is rather curious. It went down to 240 feet, and struck water that rose to within 40 feet of the surface. The other day the owner put a pump on to try and pump it out, when the water disappeared altogther, although it had been standing within 40 feet of the surface.

In the Escalente Desert we sunk a well at Sulphur Springs, which has a very good flow. In Sec. 6, R. 14 W., T. 33 S., they went down 650 feet, and only got water standing in the bore. At Iron Creek Cañon water can be got from flowing wells sufficient for irrigation. At the other points I do not doubt that a man would get good water if he went deep enough. The land in Salt Lake Valley is best adapted for grape land, both on account of soil and because grapes need less water than grain.

Mr. Fred. Trimmer, C. E., of Salt Lake City, Utah, stated that—

It is believed that in Salt Lake Desert there are underground waters. Here is the Great Salt Lake, with an area of 1,200,000 square acres. It is ridiculous to say that the vast amount of water flowing into this lake to maintain and constantly increase its level is only sufficient to irrigate 260,000 acres of land unless high mountain storage is resorted to. The great thing we need in this country is to find out more about the under or subflow; to find its channels to the lake, and take it out before it becomes salt.

The total amount of water flowing into Great Salt Lake is sufficient to irrigate 600,000 acres. That at the rate of a cubic foot per second for 100 acres would only be enough to put half a foot of water over the lake basin per annum. Now we are told that the evaporation is 4 feet 5 inches per year over the whole surface of the lake. That certainly demonstrates that there must be a large supply from some invisible source.

S. Richardson, of Richardson, Grand County, Utah, stated in illustration of the extent of the surplus or flood waters that in May he crossed the Grand River in Utah, 13 miles due south of Cisco, on the Rio Grande Western Railway, and it was running 20 miles an hour, 1,000 feet wide, and 18 feet deep. From his knowledge he considers Utah quite well watered, especially the eastern portions. "There is water enough," he said, "going to waste to put at least one million acres of land in southeastern Utah under cultivation. This is no exaggeration. A man has only got to be there to see it. The great drawback to agriculture and irrigation there is want of transportation. The average altitude is 4,500 feet."

One of the great irrigation enterprises and works is that of the Bear River Canal, which is diverted from the river of the same name about 3 miles above Colliston. The system, when completed, will have 150 miles of main canal and principal distributing canals and ditches, with laterals sufficient to irrigate 200,000 acres of land. At the point of diversion two main canals are projected on the east and west banks of the river. About 60 miles of main canal are completed, and nearly as many more of distributaries, with flumes, headgates, regulators, and other works. About 8 miles of heavy rock work in the cañon has been completed, so as to enable the canals on either side to carry the water out into the broad valley lands. Maximum flood discharge at weir site is about 8,500 second-feet; average minimum about 1,000 feet during midsummer. The diversion weir is located between high rock abutments, with its foundations in shallow rock. The weir is of crib work filled with earth and loose stones to a height of 17½ feet. The abutments widen toward the top, so that the length on the crest is 370 feet, as against 98 feet at the base. The timbers are 10 by 12 inches and built to the rock bed. There are 5 headgates, 4 feet wide by 7 feet high, made of iron, on the west side, and the same number on the east side canal, which latter for 2 miles is in heavy rock work. There are two tunnels 14 by 14, inclined, with a total length of 623 feet. The engineering is very bold.

Several deep cuts have been made, the deepest being 96 feet on the upper side. In this portion of the canal a considerable length of rubble retaining wall, laid in cement, is constructed, quite 10 feet high on the inside, 2½ feet thick at top, and 7½ feet at the grade line. Heavy fills are made across ravines, which are drained by means of culverts carried through the banks. One of these is 108 feet in depth at the center and 508 feet long on the grade. On the top rests a wooden flume, which carries the canal water. It is supported by long piling driven 60 feet into the fills.

In the level country this east side canal will have a bottom width of 50 feet and a depth of water of 7 feet, side slopes of 1 by 1 and a grade of 1 foot to the mile. It will be 50 miles in length, terminating at the Ogden River, Ogden, Utah.

For the first mile and a half on the west side it is constructed in heavy rock in a similar manner. There are six tunnels varying from 57 to 267 feet in length, with the same cross section and grade as on the east side. Above and below the tunnels are eleven retaining walls similar in construction to those on the other canal. The canal has a bed width of 1[illegible] feet 3 inches and a depth of 10 feet, with nearly vertical slopes; 1,200 feet below the head is an escape gate and a second one 600 feet further, discharging into the Bear River, with clear openings of 12 feet wide. They are closed by wooden gates sliding between iron posts let into masonry piers. Below the second escape is a regulator, with five gates 14 feet in width, constructed for the purpose of controlling the discharge in the canal. Six miles beyond this canal enters a hillside excavation of a very bold character. The bottom width remains the same.

The canal crosses the Malad River at its ninth mile, on an iron bridge with flumes 378 feet in length and 80 feet in maximum height, supported on iron trestles, having a river span of 70 feet. The approaches to the bridge are wooden flumes 500 feet in length and 20 feet wide in the clear and 7 feet deep. The flume over the bridge is also wooden and of the same dimensions. There are three falls of 7 feet each. This canal terminates at Salt Lake.

Six miles below the head of the west side canal a branch is diverted to Corinne. It runs 20 miles at its head, it is 22 feet wide on bottom, and carries 5 feet of water and is controlled by a double set of regulation gates. Both in the main and Corinne Canals the bottom and sides are protected by wooden wings. In the Corinne branch there are 16 vertical falls varying from 4 to 12 feet in height. The Malad River is crossed 14 miles from the head, on an iron bridge founded on piles and iron cylinders founded on concrete. The peculiarity of the bridge is that its superstructure, which is of iron-plate girders, constitutes the flume for carrying the water, with wooden flumes in the cab on either side. There are several inverted siphons or culverts of wood on this line, carrying the drainage under the main canal. One of them consists of two tunnels of 8 by 8, which have a clear waterway of 5¾ by 2⅓.

During the past year, 1891, there has been constructed what is known as the North Point Consolidated Canal, which adds 14½ miles to the ditches on the west side of the Jordan River. The bottom width is 50 feet for the first 3½ miles of its length, and the remainder varies from 20 to 15 feet bottom width. It will carry 93 cubic feet per second. The duty of water on the soil irrigated is 150 acres to the second foot, and it will therefore increase the irrigation in this valley 14,000 acres.

The Swan Lake Reservoir and Canal Company is a recent enterprise which is still in process of construction. It consists of a reservoir fed by the Sevier River, covering an area of 70 square miles, and located in the central portion of Millard County, 5 miles from the Union Pacific Railway and 15 miles northeast of Sevier Lake or Sink. This reservoir consists of a number of natural depressions, requiring only slight construction work to appropriate and adapt them to the requirements of the reservoir.

The continued action of the river current has built up walls or natural levees which rise to a height above the surrounding country like the levees of the Mississippi and other streams. The company in constructing their reservoir repair the natural walls, build strong dikes across channels, cut ditches and canals, build dams and flumes. There are at present over 200,000 acres of level, fertile, and irrigable land lying under the reservoir supply. About 15 miles of canal have been completed.

The lake reservoir when full will hold about 3,500,000,000 cubic feet, or 200,000 acre feet. In May, 1891, when the river had its rise, the flow over the waste dam was 30,000 miners' inches. The irrigable land is underlaid with clay a few feet below surface. The area to be reclaimed is estimated at 75,000 acres.

Another enterprise, begun during 1891, contemplates the control of Utah Lake, and is known as the Oquirrh Water and Land Company. It has for its object the lowering of the Jordan River at the outlet and below Utah Lake. The present river bed is much higher than the bottom of the lake and acts as a bar to the lowering thereof and to the obtaining of a large supply of water that can not now be utilized, and which when so utilized will be restored in the winter. Such a lowering will, it is claimed, also admit of a better regulation of the rise and fall of the lake. This lowering of the outlet will permit the irrigation of possibly some 25,000 acres, and by storing in the Provo River this can be still further augmented. There are some objections and criticisms raised against these propositions.

In cities the municipal corporations control the waters, watermasters being appointed to regulate the division of the water. The following synopsis of laws relating to Utah were compiled and furnished by Col. Charles L. Stevenson, C. E., president of the Polytechnic Society of Salt Lake City:

Whenever public necessity requires it, the county court may organize the county, or part of it, into an irrigation district, and the landholders therein may use the water brought into the district according to their respective needs, provided they pay and perform their proportion of the necessary expenses and labor. They may, on due notice, elect trustees, a secretary, and a treasurer.

The trustees shall locate the ditches and estimate all costs and reports to the county court. If the report be approved by a two-thirds vote, a tax shall be assessed and the ditch constructed.

The trustees have general supervision of the construction, maintenance, and regulation of the ditches; they may hold such personal property as is necessary to the performance of their duties; may sue and be sued, and may have appraised and sell any unclaimed lands that are to be benefited, and apply the proceeds to the construction of the ditches.

Lakes and ponds may be used as reservoirs, provided they are not raised so as to injure settlers upon their banks.

In case of inundation or other sudden emergency the trustees may take measures for protection.

Property and money in the hands of trustees to be used on the ditches is exempt from taxation.

Ditches have the right of way, a proper compensation having been paid.

Any person injuring a ditch or any of its appurtenances is liable in damages and to a fine and imprisonment.

The district is liable for damages caused by the breakage of a ditch.

The rate of tax at any election subsequent to the first may be determined by a majority vote, and the tax thus assessed shall be a lien upon the taxpayer's interest in the ditch and a right to use the water.

By act of February 20, 1880, the selectmen of the several counties are made water commissioners, who have a kind of superior jurisdiction of the water rights in their respective counties.

They determine claims relative to the use of water, oversee either personally or by agents its distribution, and determine questions of right of way, etc.

They also issue certificates showing the extent of water rights.

A person first taking water from any source of supply, or having the open, peaceable, and continuous use of the water for seven years, has a primary right therein to the extent of the reasonable use thereof.

Whenever persons having primary right use the water for a part of the year only, the person appropriating it for the balance of the year acquires a secondary right.

Water rights may be measured in inches or by fractional parts of the whole supply. Water rights may pertain to the land or may be personal property, as the owner may elect, and a change of place shall not affect the right to use the water, but no change of place shall be made to the injury of another owner without just compensation. Neglect for seven years to use water, or keep in repair the means of conveying it, is regarded as an abandonment of the right.

Water rights are exempt from taxation, except for the purpose of regulating the use of the rights, but the increased value of the land may be regarded in making the assessments.

Surplus water must be returned to the natural channel, and any person wasting it is liable to have his supply shut off, and to pay damages to any person injured.

Any person using water lawfully appropriated to another, or diverting the flow of water lawfully distributed, or injuring any dam, ditch, etc., is guilty of a misdemeanor.

Whenever the supply is not sufficient for all purposes, the use for domestic purposes and for irrigation purposes takes precedence in that order.

Corporations may be formed under general laws for distributing water to their stockholders.

STATISTICS OF IRRIGATION IN UTAH.

The meeting in Salt Lake City of the Irrigation Congress gave activity to the collection of data. The following table, prepared by Charles L. Stevenson, C. E., of Salt Lake City, is presented here with the indorsement of this office. The methods of collection are known, and the care and pains devoted to the proper presentation of the same appreciated. The total given of total acreage of "irrigable lands" is of course understood to be an estimate. By many good authorities a much large area is considered available for reclamation. This office agrees with them:

County.	Under irrigation ditches.	Actually irrigated, 1890.	Cultivated, 1890.	Irrigation season begins.	Irrigation season ends.	No. of times lands irrigated during season.	No. of hours land is irrigated each time.	Elevation above sea.	Depth of snow in adjacent mountains.	Duty of water per cubic foot per second.
	Acres.	*Acres.*	*Acres.*					*Feet.*	*Feet.*	
Beaver	9,000	6,350	6,350	May 15	Aug. 15	8	24	5,000-6,000	4	
Boxelder	120,695	9,708	26,177	May	August	8	1½	4,000-5,000	3	
Cache	66,654	30,951	54,301	....do	September	8	4	4,500	3	150
Davis	19,530	10,591	23,161	April	October	10	2½	4,200-5,000	3	
Emery	23,415	13,062	14,363	March	November			3,900-4,500	4	
Grand		1,375	1,416	Apr. 15	Oct. 1			5,800-6,300		
Garfield	12,029	7,635	8,635	April	August	8	5	6,500	3	
Iron	8,197	3,956	4,523	....do	November	6	6	5,000-6,000	4	80
Juab	8,100	4,914	9,489	May	September	10		5,500	8	
Kane	1,463	722	1,087	Apr. 1	October	8	12	5,500		75
Millard	88,586	8,152	8,152	Apr. 15	Aug. 15			5,500	3	
Morgan	7,924	5,633	5,633	May 20	Sept. 1	7		4,000-5,000	6	100
Piute	17,172	9,918	9,918	April	September	5	8	5,000-7,000	4	
Rich	31,484	26,099	26,099	....do	August	3	3	6,000	5	
Salt Lake	53,086	29,107	30,555	May 15	Sept. 15	8		4,300	6	100
San Juan	1,107	927	927					5,000		
Sanpete	45,102	33,859	47,113	May 15	September	5	24	5,550	6	95
Sevier	29,106	15,340	15,340	April	October	5	12	4,000-7,000		
Summit	18,743	14,550	14,550	May	September	3		5,845	5	
Tooele	14,400	5,343	7,524	March	....do			4,600	2	80
Uintah	17,826	10,054	10,054	April	October			4,600	6	
Utah	79,380	53,586	60,520	March	September	8		4,600	4	
Washington	9,533	4,203	4,203	April	October	12	3	2,700-5,000	4	40
Weber	33,344	17,004	22,450	May	....do	12	2	4,500	2	
Wasatch	19,350	10,365	10,824					6,000-7,500	6	
Total	735,226	333,404	423,364							

NOTE.—The total acreage of irrigable lands in Utah Territory is.... 2,304,000
The total acreage covered by present ditches is.......... 735,226

The total additional acreage susceptible of irrigation is.... 1,568,774

Joseph Lippman, Territorial statistician of Utah, in his first annual report to the Territorial secretary, presents the following table and explanation, showing by counties the number of acres under cultivation, the number of acres irrigated, and the number of acres under inclosure for pasture in Utah during 1890. In a few instances the figures show a greater number of acres as irrigated than are given as cultivated in a particular county. This is explainable on the theory that many farmers do not look upon the raising of alfalfa, although it requires irrigation, as a cultivated product, and hence, while they have included the alfalfa field in the "irrigation acreage," they have not included it in the "cultivation acreage" returned to the county assessor.

Number of acres under cultivation, irrigated, and under inclosure for pasture.

Counties.	Under cultivation.	Irrigated.	Under inclosure for pasture.	Counties.	Under cultivation.	Irrigated.	Under inclosure for pasture.
	Acres.	*Acres.*	*Acres.*		*Acres.*	*Acres.*	*Acres.*
Beaver	5,558	6,350	2,161	Salt Lake	30,555	29,107	14,415
Boxelder	26,177	9,708	35,938	San Juan	809	927	2,005
Cache	54,301	30,951	23,378	Sanpete	47,113	33,859	11,185
Davis	23,161	10,591	12,232	Sevier	8,118	15,340	6,185
Emery	14,363	13,062	8,223	Summit	14,508	14,550	702
Garfield	1,716	1,990	1,145	Tooele	7,524	5,343	11,367
Grand	1,416	1,375	2,827	Uinta	8,960	10,054	1,943
Iron	4,523	3,956	1,098	Utah	40,195	36,586	16,008
Juab	9,489	4,914	7,372	Washington	4,203	4,203	
Kane	1,087	722	4,931	Wasatch	10,824	10,365	352
Millard	8,152	8,152	7,308	Weber	22,450	17,004	17,107
Morgan	5,633	5,633	3,120				
Piute	7,779	9,918	3,425	Total	374,340	310,759	205,895
Rich	15,726	26,099	16,468				

Mr. Stevenson's figures are based upon reports from officers of the Mormon Church, while Mr. Lippman's were gathered through the usual territorial channels. The figures of the United States Census Office, as presented in Bulletin No. 85, are given below. They relate to the crop and acreage of 1889–90, but only include the irrigated portions of the areas under cultivation.

Utah irrigation statistics in the United States census for 1890.

Counties.	Number of irrigators.	Total irrigated acreage in crop.	Average size of irrigated farms, in acres.	Average value of products per acre.	Counties.	Number of irrigators.	Total irrigated acreage in crop.	Average size of irrigated farms, in acres.	Average value of products per acre.
Beaver	200	7,682	38	$9.92	Salt Lake	1,264	25,392	20	$26.73
Boxelder	359	10,472	29	15.25	San Juan	38	777	20	27.95
Cache	908	30,923	34	14.30	Sanpete	1,155	30,938	27	15.18
Davis	585	12,866	22	32.93	Sevier	311	11,517	87	11.53
Emery	264	7,344	28	17.01	Summit	276	10,140	37	15.03
Garfield	82	2,234	27	11.64	Tooele	267	5,765	22	14.46
Grand	56	1,138	20	19.05	Uinta	186	7,611	41	10.61
Iron	193	3,539	18	14.94	Utah	1,161	25,236	22	22.50
Juab	85	1,946	23	11.05	Wasatch	250	6,475	25	10.22
Kane	107	1,798	17	21.81	Washington	176	2,251	13	32.19
Millard	304	8,199	27	14.58	Weber	928	21,335	23	22.72
Morgan	233	5,298	23	18.16					
Piute	143	5,299	37	11.03	Total	9,724	263,473	27	18.03
Rich	181	17,266	94	9.00					

The totals of agricultural products, quantity, values, and of acreage for 1890 are also taken from Mr. Lippman's report:

Products.		Quantity.	Average to acre.	Acres.	Value.
Wheat	bushels	2,409,454	22	110,114	$1,927,563.20
Oats	do	1,132,218	34	32,763	532,142.46
Corn	do	165,067	19	8,776	118,848.24
Barley	do	212,546	29	7,358	106,273.00
Rye	do	45,201	12	3,759	27,574.44
Lucern	tons	306,100	3	101,729	2,715,107.00
Hay	do	120,572	1.49	80,647	1,637,367.76
Potatoes	bushels	935,874	119	7,845	496,013.22
Beets	do	21,726	248	87	7,604.10
Cotton	pounds	4,200	600	7	462.00
Orchards	do	8,246,062	1,563	5,275	206,151.55
Vineyards	do	565,560	2,134	265	33,933.00
Other products, vegetables	do	16,688,841	6,426	2,597	500,665.23
Totals		....	....	361,222	8,300,705.80

This shows an acreage value per acre of crop production in 1890 on irrigated and unirrigated land combined of $22.19 per acre. The total average presented by the Census Office in "Census Bulletin No. 85, Irrigation in Utah," $18.03 per acre, value of product on irrigated land, is in striking variance with this. A careful and conservative estimate will raise the value of the average product of irrigated land in Utah to at least $23 per acre.

The following average yields per acre in staple crops, taken from the same report, will be of interest.

Product.	Average yield per acre throughout the Territory.	Average price per unit of measurement.	Value per acre.
Beets	218 bushels	$0.35	$86.80
Cotton	600 pounds	.11	66.00
Potatoes	119 bushels	.53	63.07
Lucern	3 tons	8.87	26.61
Hay	1.49 tons	13.58	20.23
Wheat	22 bushels	.80	17.60
Oats	34 bushels	.47	15.98
Barley	29 bushels	.50	14.50
Corn	19 bushels	.72	13.68
Rye	[illegible] bushels	.61	7.32

The total value of all outputs of "ranch and range," besides those named before, are given by Mr. Lippman as follows:

Wine	$28,697.40	Dried peaches	$19,645.23
Cider	21,478.80	Dried apricots	1,486.88
Vinegar	6,976.75	Dried plums	841.38
Sorghum	37,440.00	Dried pears	992.10
Butter	323,303.23	Wool	1,229,456.58
Cheese	37,181.25		
Honey	76,894.83		1,796,224.45
Dried apples	11,830.02		

Withholding the wool product from the sum total given, the figures will be a little in excess of the total values of agricultural products already given. These totals speak well for the industry and thrift of the farmers of Utah, and they indicate what may be expected of the Territory and its population as the water supply thereof and its economic management is better understood and more intelligently administered.

Elevations above sea level of prominent locations in and near Salt Lake City.

United States monument, southeast corner Temple Block	4,357.23
Bench mark, odd tank, City Creek, southwest corner of reservoir	4,495.64
Bench mark, stone door step, buck tank, Lown system, City Creek	4,578.86
Surface of water buck tanks	4,577.90
Surface of water tank, north bench system	4,712.40
Surface of water, Capital Hill system	4,746.05
Platform new reservoir First South street east	4,587.70
Proposes surface of water, same reservoir	4,587.10
Bottom of Parleys Canal, First South street crossing	4,744.60
Pipe line (14-inch) Emigration Creek, First South street	4,755.00
Pipe line (14-inch) Emigration Creek, Wagoner's Brewery	4,965.00
Pipe line (14-inch) Emigration Creek gate house	5,051.00
Liberty Park Wells, flume crossing, Seventh street east	4,295.00
Corner of Ninth North street and county road	4,283.00
Denver and Rio Grande western station	4,252.00
Denver and Rio Grande western station, Provo	4,544.00
Bench mark and shore, Utah Lake, Thompsons Baths	4,517.35
This bench mark is 4 feet 3¼ inches above lowest water in 1889.	
Highest water, Utah Lake, June 5, 1890	4,517.47
Lowest water, Utah Lake, October, 1889	4,513.06
Trimpanagac River, monument road	4,855.92
Surface water, Trimpanagac River	4,845.41
City Creek, mouth of cañon	4,361.00
Emigration Creek, mouth of cañon	4,919.30

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers received to circulars sent by this office:

CACHE COUNTY.

Logan (post-office), J. W. Sanborn, Agricultural College (September, 1891):

Area of arable land (in county), 200,000 acres; irrigable land, 150,000 acres; irrigated land, 100,000 acres; 50 acres by artesian wells.

Water supply: Streams from Wasatch Mountains, through Logan and other cañons and artesian wells.

Works: About 206¼ miles ditches, various sizes. One reservoir at Newton; capacity, 25,000,000 cubic feet; 40 head gates for Logan, Hyde Park, and Smithfield, or 6 miles of canal; about 100 artesian wells, mainly for stock, but about 50 acres irrigated by them.

Cost per mile of ditches: "Most costly one, through ledges, $12,500 per mile;" others vary, down to very low cost.

Average cost per acre of works: Ditches, etc., from $5 to $15; average, probably $8; cost of each watering, 12½ cents per acre; annual maintenance and repairs small; cost per acre of furrow ditches over fields for flooding, from 10 cents to 50 cents.

Products: Alfalfa, clover and grass, wheat, oats, corn, sorghum, potatoes, etc.; some fruits.

Yield per acre: Alfalfa, 3 to 6 tons; grass, 2½ tons; wheat, 30 bushels.

Hyrum (post-office), H. P. Hansen and A. P. Rose (October 1, 1891):

Water supply: Two mountain streams, Blacksmith Fork and Little Bear River, supply sufficient in ordinary seasons.

Irrigation works: About 20 miles ditches; from 4 to 8 feet on bottom; 8 to 12 feet on top; many head gates. No reservoirs, but they are needed badly, and settlers are not able to build them.

Average cost per acre for their main ditch, $2.50; annual maintenance and repairs, $1.25 to $1.40 (including irrigating).

Area irrigated in this precinct: About 4,000 acres; also 600 city lots, each 1¼ acres, which are irrigated once a week for three months, at a cost of $6.

Products: Wheat, oats, barley, potatoes, and other vegetables; also fruit of various kinds.

Estimated value of annual product per acre, $10 to $15.

DAVIS COUNTY.

Kaysville (post-office), Elijah Laycock (September, 1891):

Water supply of neighborhood: Four mountain creeks or streams, fed by melting snows, etc.; also artesian wells. Water taken from creeks in small ditches 2 or 3 feet wide. Water supply of these creeks is divided into "primary shares," worth $25 each (share represents water for one acre for the whole year). There are also secondary shares, worth $12.50 each, which take water until June 1 only. (Some shares water a part of the town.)

Cost per mile of ditches, about $100.

Area in neighborhood covered by ditches, about 4,000 acres.

Area under ditch from creek in which Mr. Laycock is interested is about 2,500 acres; under cultivation, 2,000 acres; annual cost for maintenance and repairs for ditches from this creek, not over 10 cents per acre.

Average cost per acre for preparing land for cultivation under irrigation, about $3.

Chief products, wheat, barley, oats, alfalfa, potatoes, etc., and fruit.

Estimated average yield per acre: Wheat, 25 bushels; barley, 35 bushels; oats, 40 to 50 bushels; potatoes, 100 to 600 bushels.

GRAND COUNTY.

Moab (post-office), secretary "Moab Irrigation Company" (September 12, 1891):

Average cost per acre in vicinity for preparing land for cultivation under irrigation, about $10 (clearing and breaking).

Average cost per acre of irrigation works, ditches, etc., about $4 (under that system); for maintenance and repairs, 25 cents.

Area under cultivation, 1,000 acres; 200 or 300 acres under ditch as pasture.

Chief products under irrigation: Alfalfa, fruit, grapes, and corn (in the order mentioned).

Yield per acre and value of product: Hay, 5 tons, $6 per ton; fruit, no estimate; grapes, $1,000; corn, 30 bushels, at $1.20 per bushel.

SALT LAKE COUNTY.

Salt Lake City, Wilford Woodruff, and John R. Park, M. D. (September 1891):

Area in county under ditch, 53,086 acres; under cultivation, 30,555 acres.
Water supply: Streams fed by the melting snows of the Wasatch range of mountains; also artesian wells.
Irrigation works in county, about 175 miles; main canals, varying in width on bottom from 10 feet to 20 feet. No reservoir.
Average cost per acre for works, ditches, etc., $9 to $10.
Average cost per acre for annual maintenance and repairs, 80 cents to $1.
Average cost per acre for preparing land for cultivation under irrigation, $2 or $3.
Cost of water supply to user per acre, $1.50 (under Bear River system).
Chief products under irrigation: All cereals, vegetables, and fruits natural to the temperate zone.

TOOELE COUNTY.

Tooele City, C. A. Herman and John C. Shields:

Water supply: Cañon streams from the Oquirrh Mountains. (District has 800 miner's inches at 6-inch pressure.)
Area under cultivation, 3,000 acres. (There are 50,000 acres of good, arable, vacant land in Tooele Valley, that with a water supply would yield as fine crops as are raised on any irrigated land in the Territory. Two-thirds of the water in this district is wasted by seepage and evaporation, for the lack of flumes, cemented ditches, or conduits, or pipe lines.)
Irrigation works, 20 miles main ditches, from 6 to 8 feet on bottom, 8 to 10 feet on top, from 2 to 3 feet deep; about 50 miles minor or lateral ditches (all ditches plowed and spaded); 3 head gates; small timber dams in cañons; no reservoirs.
Cost of water supply to user, per acre, from $10 to $15 (originally).
Annual rental cost of water, $1.
Cost of ditches per mile: Main, $200; laterals, $50.
Average cost per acre of ditches, etc., $10.
Average cost per acre for preparing land for cultivation under irrigation, $4.
Average cost per acre for annual maintenance and repairs, $1.
Products: Alfalfa, wheat, oats, barley, corn, potatoes, etc., and fruits.
Yield per acre: Wheat, 30 bushels; oats and barley, 60 bushels.

[Mr. Shields (a director in the Tooele Irrigation Company) reports an area of 1,568 acres irrigated by that company. Water supply: Two cañon streams; supply divided into 14 equal parts or shares, each share sufficient to irrigate 112 acres.]

UTAH COUNTY.

American Fork (post-office), T. B. Parker (September, 1891):

Water supply: Wasatch Mountain streams fed by melted snow; supply insufficient with present facilities and methods of use; storage reservoirs needed.
Irrigation works: About 15 miles of ditches; five head gates; no reservoirs or other works.
Average cost per acre of ditches, etc., $20; for annual maintenance and repairs, 50 cents.
Average cost per acre for preparing land for cultivation under irrigation, about $20.
Area under ditch, 4,500 acres; under cultivation, 1,500 acres.
Chief products: Wheat, oats, corn, hay, potatoes, and fruits.

Pleasant Grove (post-office), Robert Thorne, president "North Union Irrigation Company" (September, 1891):

Water supply: Mountain stream; regular flow 10 months; 2 months subject to freshets.
Irrigation works: 8 miles of ditches, 7 feet wide, 4 feet deep; 2 head gates; no other works.
Cost per mile, about $3,000; average cost of ditch per acre, $25.
Average cost per acre for annual maintenance and repairs, $1.
Average cost per acre for preparing land for cultivation under irrigation, $10.
Cost of water supply to user per acre, $25 (cost of ditch per acre).
Area under ditch, 3,000; under cultivation, 1,000 acres.

Chief products: Alfalfa, wheat, corn, oats, potatoes, beans, sugar beets, sugar cane, and fruit.
Value of product per acre: Wheat, 20 bushels per acre, average 75 cents per bushel. Other crops in proportion.

Provo (post-office), Judge J. D. Jones and J. E. Booth (September, 1891):

Provo Precinct: Area under ditch, 25,000 acres; under cultivation, from 15,000 to 18,000 acres. Water supply: Provo River mountain stream with capacity of from 10,000 to 11,000 cubic feet per minute in low-water season, but three times as much in the months of May and June; supply all appropriated; also a large number of artesian wells, 2-inch pipe, 200 feet deep; flow from 20 to 60 gallons per minute.
Irrigation works: Big Bench Canal, 2 miles long, 20 feet wide, 4 feet deep, 10 miles laterals; Hooper Canal, 10 miles long, 8 feet wide, 2 feet deep; Enterprise Canal, 11 miles long, 6 feet wide, 2 feet deep; Lake Bottom Ditch, 6 miles long, 6 feet wide, 2 feet deep; Timpanogas Ditch, 5 miles long, 4 feet wide, 2 feet deep; Upper East Union, 8 feet long, 8 feet wide, 2 feet deep; East Union proper, 20 miles long, 10 feet wide, 3 feet deep, with laterals; also a number of small ditches; one main head gate for each ditch; total main ditches, 60 to 65 miles; ditches generally owned by the landowners.
Cost per mile of ditches, etc., from $500 to $10,000; average cost per acre, from $5 to $30: for annual maintenance and repairs, about $1.
Average cost per acre for preparing land for cultivation under irrigation, $4 to $5; for grazing, about half that sum.
Cost of water supply to user per acre, $10 first cost; $1 to $3 yearly rental cost.
Chief products: Wheat, oats, barley, corn, alfalfa, tame and wild hay, sugar cane, sugar beets, potatoes, and other vegetables; also variety of fruits, etc.

WEBER COUNTY.

Ogden (post-office), L. B. Adams (September, 22, 1891) this:

Davis and Weber Counties Canal Company. Water supply, Weber River (near Devil's Gate, Morgan County).
Irrigation works: 9 miles main canal, 20 feet wide, 4 feet deep; 5,000 feet fluming, 8 feet wide, 4 feet deep; 20 miles of laterals; no reservoirs on main canal; several small ones, 1 to 5 acres each, on laterals; dam on main canal, temporary; no permanent one necessary; three head gates; also drop and waste weirs.
Area under ditch, 10,000 to 20,000 acres; under cultivation, about 8,000 acres.
Cost of canals and laterals, $150,000; cost per acre for maintenance and repairs, 10 to 15 cents.
Average cost per acre for preparing land for cultivation under irrigation, about $5.
Annual rental cost of water per acre, about $1.
Staple products: Wheat, oats, barley, rye, potates, sugar beets, and other vegetables; corn does fairly well.
Average yield per acre: Cereals, 20 to 60 bushels; potates, 200 to 400 bushels.

Pleasant View (post-office), George Barnett (September, 1891):

Average cost in vicinity for preparing land for cultivation under irrigation, from $10 to $12 (more on some land).
Average cost per acre for irrigation works, ditches, etc., $10 or over.
Area in neighborhood under ditch, over 2,000 acres.
Staple products: Wheat, oats, barley, corn, apples, pears, peaches, plums, apricots, strawberries, raspberries, blackberries, etc.
Average yield per acre: Wheat, 25 to 30 bushels; barley, 40 to 45 bushels; corn, 60 bushels (and over); potatoes, 300 bushels or over.

WASHINGTON.

The State of Washington, in the extreme northwest of the Union, fronts west on the Pacific Ocean; on the east it is bounded by the State of Idaho, south by Oregon, and north by British Columbia. Its breadth north and south is 245 miles and east and west 360 miles. Two-thirds is found east of the Cascade Range, which, as in Oregon, bisects the entire State. The eastern portion has an area of about 50,000 square miles, with about two-fifths of the population of the State, and is yearly increasing in importance. Hydrographically speaking, Washington is one of the best-watered areas in the Union. The Columbia, rising mainly in British territory, enters Washington at 117° 40′, passes southward to Spokane Falls, then makes a great bend through Stevens, Lincoln, Douglas, and Okanogan counties, where it turns almost directly southward to Wallawalla, and passes westward therefrom for the balance of the State, making a dividing line between it and Oregon. The Columbia River is fed within the borders of the State by several important streams. On the north the Okinakne River marks the boundary line between Stevens and Okanogan counties, and the Wenatschee River forms the northern boundary of Kittitass County. The Yakima passes entirely through the county so named from its source upon the eastern slope of Mount Tacoma.

West of the Cascade Range, from the foothills of the mountains to the ocean, the rainfall is the heaviest within the United States, ranging at the coast from 60 to 110 inches per annum. Irrigation is therefore unnecessary throughout the whole of western Washington, unless in some portions of the higher valleys of the Cascades. But little in detail is known of the higher portions, with their series of culminating peaks from Mount Baker in the north to Mount Adams in the south. The eastern surface of the Cascades will present longer valleys, less precipitous table lands, and a foothills and plains region somewhat similar in outline to that of the plains east of the Rockies. There are a number of important lakes in central Washington and on the eastern slopes of the dividing range. The largest of these bodies of water is known as Lake Chelan, in Okanogan County. There are a score more of considerable size which will probably be of value hereafter for storage basins for irrigation purposes. The valley lands of the Columbia are comparatively narrow so far as the water plane is concerned. The bench or mesa land seast of The Dalles are broader, possessed with fertile qualities, and presenting with moderate irrigation an immense area for wheat and other grains, alfalfa, vegetables, and smaller crops. It was estimated before the Senate Irrigation Committee in 1889 that in the central portion of the Columbia Valley, from Waterville southward to Ainsworth, at least 12,000,000 acres could be reclaimed for arable purposes, either by ditches on a large scale taken direct from the river by reservoirs with ditches attached or by storage basins to be filled by pumping from the river itself. The soil of the Columbia Valley is largely volcanic in character and possesses great fertility. The wheat-growing capacity of eastern Washington is regarded as inexhaustible, about 14,000,000 bushels being returned as the past year's harvest.

The climate of eastern Washington in its relations to agriculture must be counted as semi-arid in character. Westward from the line of Idaho to the Columbia River Valley, west and north, the annual precipitation shows a mean of about 17 inches; west of the Columbia River, from Kittitass south, the average will not exceed 10 inches. In the northern and central portions of Washington, including most of the counties of Stevens and Douglas and the whole of Okanogan, no systematic records have been made. The precipitation is probably a little less even than south of Kittitass. Taking the extreme eastern section along the Idaho line the annual mean precipitation is given as follows:

Counties.	Inches.	Counties.	Inches.
Colville and Fort Colville	16.50	Wallawalla	17.85
Spokane Falls, four years' average	19.82	Dayton	26.72
Colfax	25.31	Ellenburg (central Washington)	9.00
Pomeroy	20.32		

On the north side of the Columbia, in Klickitat County, the average will be about 12 inches. The difference in precipitation, as shown in the extreme eastern part of the State, is wholly a matter of altitude, the increase being about 3 inches for each 1,000 feet of elevation. The climate of both portions of eastern Washington is generally of a delightful character. The fogs of the coast region do not rise high enough to penetrate the river basins or cross the mountain line. In many respects the general features resemble those of central California; the nights are cool, the air clear in the daytime, and the sun is seldom overcast. The winter months will give a maximum temperature, south and north from Wallawalla to Spokane, of at least 60°. West and across central Washington the mean winter maximum will be about 50°. The summer average will range from 85° to 100°, the dryness of the atmosphere, however, making the noonday's sun quite tolerable. Snow falls in December on the mountain tops, and reaches the foothills and valleys by January, being usually gone in the early part of February. The "chinook" winds find their way through the Columbia gorge and play an important part in modifying and favorably affecting the climatic conditions of southeastern and eastern Washington.

What is known as eastern Washington proper occupies the area between the Columbia River and Cœur d'Aléne and Blue Mountains and British Columbia. This region is exceedingly fertile. The soil is composed of volcanic detritus and contains a large proportion of silicates. It is entirely sub-humid in character. Water for irrigation purposes may readily be stored in small basins and obtained from artesian or drainage wells, springs, or other underflow supplies. Taking the region from north to south the precipitation will be found in the valleys and lower bench lands to range at 18 inches, and in the upper valleys and cultivatable lower mountain slopes at about 24. Water is obtainable by means of bored wells at a depth of from 40 to 100 feet. The conditions in central Washington and along the great valley areas are such as to warrant belief in the ability of the settler to obtain an abundant local supply from drainage sources. Wells for stock purposes and domestic use, which may also be utilized to irrigate gardens and orchards will everywhere be readily bored and supplied with water. There are eight artesian flowing wells inside of the corporate limits of Pullman. They are 5-inch bore and discharge each from 700 to 1,000 gallons per minute. This water is obtained at a depth of from 75 feet to 95 feet.

From one of these wells the town is supplied for fire protection and use. The cost of boring is $4 a foot for rock and $1 for dirt. We go through a solid rock until the sandstone, in which is the water, is struck. In one of the wells, after the rock, a stratum of slate rock, then of coal, was struck, but the water flowed when in the slate rock. The water in one of the wells is strongly impregnated with iron and has medicinal properties; 25 feet from the surface is the highest the water would rise in any of these wells, carried up in pipes. All attempts to strike the flow outside of the town have failed.

The area reported under ditch in 1889 was 75,000 acres, of which 50,000 was in process of cultivation. In the Yakima Valley some 12,000 acres were being cultivated, 5,000 of which was in one farm, known as "The Moxey," belonging to a company of Eastern capitalists, which is maintained in a comparatively fine state of cultivation. It is estimated that in the valley of the Yakima alone 200,000 acres could be brought under cultivation by means of irrigation works at a comparatively small cost. It is further stated that with more extensive reservoirs and larger canals under proper engineering a million and a half of acres can be reclaimed within the hydrographic basin of the Yakima by means of the water supply thereof. In central Washington, the neighborhood of Ellensburg, in Kittitas County, is one of the finest valleys in the arid section. Some 22,000 acres of land were under cultivation in 1889. The increase for the past year will make this area about 25,000 acres. The waters which serve this area are brought successfully through a tunnel of considerable length made through the mountain range, on the slope of which Ellensburg stands. Ditch ownership in eastern Washington is, with but one exception, of a mutual character, the stock being taken by farmers whose lands are served by the waters which the ditch conveys.

Under irrigation the production given at various points in eastern Washington presents the following averages:

Product.	Quantity.	Product.	Quantity.
Wheat ....bushels..	35 to 40 45 to 50	Onions ....tons..	25
Barley ....do....	30	Cabbage ....do...	15
Oats....................do....	35 to 40	Carrots....................do..	50
Potatoes ....do....	500	Beets....................do...	20 to 40

The larger yield of wheat given is that of the Walla Walla country, so also is that of vegetables stated. Fruit-growing in southeastern Washington is one of its most important industries. Some 1,200 acres, for example, are cultivated within a small radius of Walla Walla. Of fruit and vegetable products, the return per acre is estimated at $400. The yield and price per acre as given before the Senate committee were as follows:

	Selling price.	Total value per acre.
Grapes, 10 tons	$60 per ton..........	$600
Strawberries, 10,000 pounds....................	6 cents per pound. ...	600
Blackberries, 12,000 pounds....................	7 cents per pound	840
Raspberries, 5,000 pounds....................	7 cents per pound.....	350
Melons, 300 dozen....................	$1 per dozen	300
Tomatoes, 600 boxes	30 cents per box	180

On 613 acres of garden and fruit land the total for the year was $4,731. The total investment for purchasing and putting in operation is estimated at $3,600 and the cost of working per year at $1,500; the profit will therefore be nearly 100 per cent. The fruit marketed was raised by irrigation. It is claimed that while good crops can be raised in the semihumid section of Washington the secret of security and largest yields is found only in the proper storage and service of water.

The Northern Pacific Railroad Company have, it is understood, decided upon large investments for storage and irrigation works within what is known as the Big Bend of the Columbia. That river where it enters this region flows through a deep and narrow valley nearly or quite 1,500 feet above the general level. Below it enters a comparatively low and level plane. The land to be reclaimed is located within Lincoln and Douglas counties. Several million acres, it is estimated, will ultimately be placed under ditch. The climate of the region is considered equitable and is especially free from strong winds on account of its being encircled on the east and north by mountain ranges. The average rainfall will probably not exceed 14 inches. Streams are not frequent; several lakes are located in the section. Phreatic waters are found at a depth of from 4 feet in the draws and 40 feet in the lower foothills. The temperature in winter is like that of western North Carolina. Without irrigation wheat brings 25 bushels to the acre; corn also produces well for no large demand; barley averages 55 bushels, oats 60 to 70. With irrigation this average it is claimed can be largely increased. As a stock country it is regarded as the best on the continent.

Great activity is reported for the past year at North Yakima and in the adjacent region. The Yakima County Irrigation Company, organized late in 1888, now has under ditch an area of 30,000 acres. The original settlement of six families has increased to fifty. Land valued at $2.50 per acre before settlement is now held at from $30 to $50 with water. The sources of the water supply in this county are the Yakima and Columbia rivers. Farms range in size from 40 to 150 acres. Landowners also purchase an inalienable right to the water. They are holders of stock in the ditch. The duty of water is 1 miner's inch per acre. The railroad irrigation works proposed in this region, which have been surveyed during the past year will, it is expected, serve 500,000 acres. The canal length will be 100 miles. The Selah Valley Ditch Company organized in 1888 was surveyed and constructed to serve 15,000 acres of land, which are now under ditch. The source of supply is the Naches River, the water of which is conveyed by ditch and flume to the land. Irrigated land before the construction of ditches is valued at $2 per acre. Its present value with water is estimated at $40; without water, at $5. The duty of water is but one-half miner's inch per acre. Farm holdings average 80 acres each. The Fowler Ditch Company was organized in the spring of 1889 to serve 6,000 acres. The source of supply is the Yakima River. The crops raised are fruits, wheat, oats, potatoes, alfalfa, vegetables, hops, and grasses. The yield is estimated at 50 per cent more than on nonirrigated land, however favorably the latter are situated for natural subirrigation.

Recent reports from Kittitas County, another important center of irrigation works, give encouraging accounts of progress within the past year. At Ellensburg the Westside Irrigating Company, the latest corporation in operation, was organized in June, 1889. The stock is owned by about 40 farmers, and the land served covers an area of 10,000 acres. Before irrigation land was worth $1.25 per acre; with water supply it ranges from $25 to $150 per acre. The sources of supply are the Yakima River, the Tanems and Manastash creeks. The works consist of a ditch 14 miles in length with a grade of 20 inches per mile, and with the estimated capacity of 3,000 miner's inches, or 4,500 cubic feet per minute. The duty of water is estimated at one-half inch per acre. A permanent water right costs $30 an acre and the water belongs to the stockholders. Under State law in Washington water is public property to be used for beneficial purposes. Prior appropriation alone gives title, and for some purposes the right may be transferred. Crops without irrigation are, as a rule, failures. Farm holdings run from 160 to 320 acres. The general price of irrigated land under ditch will be about $60 per acre. The average duty of water in the county is 1 miner's inch per acre per second. Wheat on irrigated land returns 60 bushels per acre, barley 50, oats 50, and other crops in the same proportion. The Watts Ditch Company have 140 acres under ditch. The Manastash Water Ditch Company, organized in 1872, serves an area of 1,500 acres. The works are an open ditch and short flumes for small laterals. The duty of the water is 1 miner's inch per acre.

Mr. Kirk Whited, of Wenatchee, writes as follows in relation to irrigation in Kittitas County:

> Through this part of the country the Columbia River flows in a deep channel from 30 to 70 feet below its immediate banks. In many places the mountains rise abruptly from the river, while in other places there are valleys of various widths up to three miles. The soil in these valleys is rich, but requires irrigation to be productive.
>
> On the east and south of the Columbia is a rolling plateau from 1,500 to 2,500 feet above the river, and only small streams come in from that side. On a strip of this Big Bend plateau about 25 miles wide following the course of the river, the rainfall is sufficient to produce grain without irrigation, but the valley below is dry and hot in the summer. On the west and north side of the Columbia the country is principally mountainous, with fertile valleys, some of them containing several thousand acres; the streams are more abundant and the waters in many cases are being utilized for irrigation.
>
> On the west side of the Columbia River the Quiltoechiro and Stemilt creeks and several small streams coming out of cañons furnish about one-fourth enough water for the valley; there are two or three associations of settlers and several individuals who have taken ditches. If plenty water were supplied to the main valley, that which is now taken from the two creeks could be profitably used on higher lands.
>
> The Wenatchee River is about 400 feet wide, 3 feet deep, and has a fall of 13 feet per mile in the lower part of its course, and runs in a deep channel much below the surface of the valley. A preliminary survey for a ditch was made last spring. The line proposed lies on the south side of the Wenatchee, and starts about 25 miles above its mouth. The broken nature of the country will make such a project very expensive and at present, at least, impracticable.
>
> A ditch to irrigate that part of the valley lying north of the Wenatchee is believed to be practicable, and steps are being taken with that end in view.
>
> East of the Columbia is a tract of 15,000 acres (shown on the map) lying on two benches that would be very productive land for fruit and other crops if supplied with water, but there are no streams and only one or two small springs on the whole tract, and the Columbia having a fall of only 2 or 3 feet per mile it is impossible to take a ditch from that river. The Columbia River at this point is 550 feet above the sea level, the climate in summer is dry and warm, the winters are mild, so that all the fruits and vegetables of the southern United States thrive to perfection.
>
> As the Columbia River flows in a deep valley between a high plateau on the east and the Cascade Mountains on the west, it is believed by many that flowing water can be obtained by boring artesian wells near the foot of the hills, and that this is a favorable place for the experiment. If it should prove a success here, others would be sunk in many places along the river.

In the extreme southeastern section of Washington—that is, Asotin County—there are a number of small farm ditches in use for the supply of the farms. The mileage or acreage is not given, but the extent is yet small. On the Idaho side of the Snake River, however, by which this county is watered, a considerable use of the river is made by means of lifting through steam pumps and distributing water thereby on valuable orchard lands. Throughout this section of Washington no large works are reported. Many large springs on the north side of the Columbia River are used for garden and fruit purposes. The cost of the plant employed is generally $100,000, which serves from 2 to 40 acres. These small works extend along an area of 120 miles. Nonirrigated lands of this character will sell from $2 to $10 per acre; with springs and wells that can be used for fruit and garden irrigation, sell at from $75 to $100 per acre. In Whitman County, where Pullman is situated, water is seldom used except to irrigate small farms and fruit areas, but increasing interest is being manifested in the advantages to be derived in the storage and use, at proper periods, of the waste water of the wells for fruit cultivation. In Franklin County no canals outside of individual farms are reported. Some small ditches are in use. At Pasco the use of well water for irrigation purposes has begun. The water is lifted by means of steam pumps, serving some 60 acres at a cost of $12,000. This was set in operation during the past year, and no results have as yet been achieved. Farm wells are dug and bored, reaching water at a depth of from 10 to 125 feet below the surface. The power used for lifting is generally that of windmills and horse power. Under the recent law adopted by the State legislature, an irrigation district has been formed in Franklin County embracing 19,500 acres. It is proposed to lift the water 115 feet by steam pumps from the Columbia River. The volume will be 20,000 gallons per minute, which will then be distributed by canals over the land to be served. In Walla Walla the irrigation system is entirely with small farm ditches; no corporate or associate efforts exists therein. The underflow of water in this county is near the surface and quite abundant. Wells are generally sunk and water is raised by means of windmills and other mechanical power. Well water and springs are commonly used for orchard and garden irrigation.

The following statements are compiled from data sent to this office in reply to circulars, or are gathered from other credible and authenticated sources:

On the west side of the Walla Walla River an enterprise of considerable magnitude is in progress. Surveys were made late in 1891 for canals to be constructed on both sides of the river, but no other report has yet reached this office. The Walla Walla country is one most favorable for the raising of fine fruits and vegetables. It is also almost the center of one of the greatest wheat-growing sections of the United States. This is not an arid section, but must be classed as sub-humid in character; the storage and distribution being valuable for the purpose of security in farming operations.

The canal of the Northern Pacific, North Yakima, and Kittitas Irrigation Company takes water from the Yakima River some 10 miles below North Yakima. The head works consist of a low concrete dam with butterfly weirs arranged to fall at high water and divert some 450 cubic feet of water per second into the company's canal at all times when irrigating may be in progress. The canal is designed to be about 60 miles long, and about 30 miles are actually being built. The cross section is 30 feet at the bottom, slopes 2 to 1 inside, 1½ to 1 outside, berm 6 feet wide, bank 8 feet high. All excavated material is used to strengthen the banks and none is wasted. The cut is 20 per cent of fill. The grade is 3 feet in 1,000, and the estimated depth of water is 6 feet. The material passed through is generally a fine volcanic soil, exceedingly rich when watered, but so fine and dusty as to be very difficult to handle. The lateral system for this canal has not yet begun. It has been proposed to introduce wrought iron pipe, as the slope of the land from the canal towards the Yakima River is in many places too steep for the economical use of ditches.

The 65 miles of canal are designed to cover 60,000 acres. A second canal, of the same section but of greater length, is proposed to water another 60,000 acres lying above the present work. This second or "High Line Canal," if built, must cross the Yakima River in an inverted siphon, after passing through several miles of flume. In connection with this canal will be a series of natural storage reservoirs, supplemented by timber-crib dams in the headwaters of the Yakima and Nachess Rivers. The most novel scheme for Eastern Washington is that of the Yakima Land Company, embracing 10,000 acres of the upper Moxee Valley. In November, 1890, an expert report on the probability of finding artesian water in a country believed to be volcanic in its formation was obtained. The report was favorable and work begun at once. One well was sunk during 1891 into a stratum of water-bearing sandstone, and it yields through a 6-inch pipe a flow of 1.13 cubic foot per second. A second well, 10 inches in diameter, is believed to be entering the same stratum. This discovery of water-bearing sandstone in the high lands of eastern Washington, with its attendant circumstances of freedom from malaria and typhoid fever, is one of the greatest advances made in the last few years in that rapidly growing State.

The farmers of the Cowchee and Wide Hollow valleys have organized an irrigation district, under recent State law, similar in character to the California system. The Selah Ditch Company are again active, and their service, if completed, will assist a very fertile tract. Another enterprise proposes the reclamation of 15,000 acres along the Columbia River and within Yakima County. Interest in irrigation is steadily increasing.

The views of a prominent business man interested in a large irrigation project in Yakima County, Wash., are presented as illustrative of what organizers and administrators claim to be an error in our land laws. To a special agent of the Department and this office, Mr. R. K. Nichols, the mayor of North Yakima, said:

> One of the evils which irrigation schemes have to contend with is the persistent blackmailing to which they are exposed from "squatters." This in many instances amounts to a practical obstruction of irrigation development. While it is true that the Government grants the right of way to canals and ditches for irrigation over and through its lands, yet the class of persons who follow along behind the surveyors in running the preliminary lines of irrigation companies, and as soon as they can ascertain from the stakes the necessary localities which the irrigators must secure for their canals or works, they at once file upon them and commence settlement, in order to compel the promoters of the enterprise to buy them out or else resort to the tardy method of "condemnation." This is a crying evil, and has been carried to such an extent as in many instances to drive off weak companies, who otherwise would have proceeded and opened up large and valuable tracts of arid lands to settlement and cultivation.

This is entirely from the corporation point of view, however.

Mr. Nichols recommends Congressional enactment, so that whenever an individual or company engaged in promoting irrigation enterprises shall project its lines over a tract of Government lands for its canals from the source of supply to the place or places of intended use, and shall file a diagram of this line of canal in the office of the nearest United States district land office, that such filing of the plat by the individual or company shall, *ipso facto* give him, it, or them, an indefeasible right as against every one but the Government, for all the necessary ground for a right of way along the line of their canal or ditch, not to exceed

200 feet on either side of the center line of such canal or ditch, the same to become a vested right as soon as satisfactory proof is made at such district land office of the completion of the works, and patent issue therefor.

He also observed that in the arid lands of the State of Washington, the rainfall is practically nothing, that water for irrigation has to be brought from the mountains where the precipitation of moisture is very great. That in the spring of the year the streams leading from these mountains carries a superabundant supply of water for all purposes; but that owing to their high grade along in the summer, they are drained off, and some years dwindle away to almost nothing. This difficulty, he stated, can be easily cured and an ample supply of water maintained for all seasons of the year by irrigation companies adopting a systematic system of storage reservoirs in the lakes, valleys, and cañons of these mountains; but that here again they are continually blocked by the "black-mail" scourge.

Engineers have satisfied themselves by actual measurement that there is not sufficient water at all seasons, in their source of supply, the Yakima River, for the wants of their canals and the requirements of the riparian owners; that they must provide reservoirs for the storage of the surplus water of the spring and early summer; therefore they proceeded up into the mountains, in and about the glaciers, and filed notices of appropriation of dam sites at the outlets of some mountain lakes, which had hitherto been valuable only as watering places for the wild beasts of the forests. Instantly, the margins of these lakes, high up in the mountains, having frost every month in the year, were found to possess wonderful agricultural properties, were settled upon and claimed by squatters, who will doubtless all in time present heavy claims for damages for flooding these valuable lands. Mr. Nichols insisted that if the Government desires these arid lands to be reclaimed and populated, made remunerative and productive, something should be done, and at once, to remove this difficulty.

Mr. Nichols suggested that an association on obtaining a certificate, signed by the governor and secretary of state of any State or Territory, declaring that such association or corporation was actively and actually engaged in the construction and maintenance of irrigation works in such State or Territory, and should, with such certificate, file a map showing the line of their works and proposed works in the office of the nearest United States district land office, and that if on such plan it should appear that certain lakes, valleys, ravines, or cañons were necessary as reservoirs for the storage of water from their sources of supply; that thereupon, by published notice from such land office, the reservoir sites delineated on such maps should be withdrawn from entry or settlement, and that upon the completion of the works of such irrigation, satisfactory proof being made thereof to such district land office, a survey at the expense of the irrigation company should at once be ordered and made and a patent issue therefor to the irrigation company, including the requisite land at the outlet for the necessary dams and works. Such a law should also, Mr. Nichols observed, be hedged about so as to sufficiently protect the Government from land grabbers and speculators.

In the Yakima Valley there are very many farmers who have already procured title from the United States and who are offering the half of their holdings as gifts to secure complete irrigation for the remainder. "Surely," he added, "if the American farmer can afford to do this-to encourage the development of this wonderful sage-brush land, the Government ought to do something."

> Why [he went on to say], there are tens upon tens of thousands of acres of sage brush where a jack-rabbit will starve; but fertilized with the necessary water, will produce in abundance anything which can be grown in this latitude; support a husbandman and his family on every twenty acres, and prosperity, peace, and happiness will reign where now only desert solitude obtains. Certainly [he added] it seems to me that it would only be wise business economy for the Government to allow the constructors of large irrigation works, the right for a certain length of time after the construction of their works of purchasing a certain portion of the Government lands under the waters of their canals, at a stated figure, say $2 or $2.50 per acre; and that these lands should be withdrawn from the market on filing the map of location of the canal, something after the manner indicated before by him, respective to rights of way and the establishment of reservoirs. * * *

In his opinion, such an act would be a great encouragement, and would energize the cause of irrigating the Government's barren wastes immensely; that as matters now stood, in view of the great cost and risk of the investment, all irrigation companies must possess great financial ability in order to accomplish anything.

ANSWERS FROM CORRESPONDENTS.

The following data has been compiled from answers received to circulars sent by this office:

DOUGLAS COUNTY.

Waterville (post-office), P. E. Berry (September 28, 1891):

"No irrigation in the county. Limited flat along Columbia River could be reclaimed by irrigation, but at very great expenditure, as water would have to be conducted from the rivers for a long distance, over much rough land in order to reach the upper flats. (Above the 'river flats' is the prairie or plateau country.) The soil of the river flats is well adapted to fruit-raising. The county is mainly productive of small grain and cattle-raising."

YAKIMA COUNTY.

North Yakima (post-office), R. Strobach (September 26, 1891):

[Surveys, etc., have been made for an irrigation system which will take its water-supply from Tietan River, proposed length about 35 miles; main ditch will carry 350 cubic feet per second, before laterals are taken out; other works, one headgate, 10 miles of flume. Cost per mile of ditches, etc., flume about $20,000; dirt and rock, from $5,000 to $6,000. Area under this system, 39,380 acres first-rate lands and 6,000 acres third rate, and cost of water per acre not to exceed 75 cents.]

Average cost per acre in this vicinity for preparing land for cultivation under irrigation, about $10 (under the district undertaking it will cost $10 for water alone on account of engineering difficulties.)

Average cost per acre of irrigation works, ditches, etc.: On small streams with great fall, from $2 to $5; on rivers, from $5 to $15; cost for annual maintenance and repairs merely nominal as yet.

Area under ditch in neighborhood, perhaps 100,000 acres; under cultivation, about 5,000 acres. (When present undertakings are carried out area will be increased to 250,000 acres.

Products: Hops, alfalfa, and fruit.

Average value per acre: Hops last year at 35 cents, earned from $350 to $500; alfalfa, from $40 to $75; fruit, from $150 to $200.

North Yakima (post-office), J. G. Lawrence (September 19, 1891):

Water supply for irrigation from streams fed by the mountain snows; supply abundant, except some years on smaller streams. "The principal portion of the land capable of irrigation by our streams is yet untouched. Artesian supply, also in great quantity, has been obtained within the last few months."

Irrigation works: Nine ditches, 12 feet each at bottom, 16 feet at top; about 100 miles of same; 1 ditch, 15 feet on bottom, 20 feet top, about 20 miles; 1 ditch, 30 feet on bottom, 60 feet on top, about 18 miles, to be extended to 90 miles. The only reservoirs as yet are lakes in the mountains (with dams of various sizes), covering an area of about 15 acres. There are also about 50 irrigation steam pumps, about 50 wheels, and a few wind pumps.

Cost per mile of ditches, etc.: Neighborhood ditches, about $50; larger ditches, from $500 to $1,000.

Average cost per acre of works, ditches, etc.: In lower valleys about 50 cents; in higher valleys, about $2. Upon the still higher or uplands ditches are now being taken out for the first time at an average cost of about $4 per acre.

Average cost per acre for annual maintenance and repairs: For smaller or farm ditches, about 10 cents; for larger or corporation ditches, from 50 cents to $1.

Average cost per acre for preparing land for cultivation under irrigation for clearing sage brush, $2; plowing, $3; total, $5.

Cost of water supply to user per acre, 50 cents.

Area under ditch, about 150,000 acres; under cultivation, 50,000 acres.

Chief products: Wheat, oats, barley, alfalfa, timothy, clover, hops, potatoes, tomatoes, turnips, cabbage, etc., apples, apricots, cherries, prunes, plums, peaches, pears, watermelons, and berries of all kinds in paying quantities.

Average yield of products per acre: Wheat, 40 bushels; barley, 40 bushels; oats, 50 bushels; hops, from three-fourths to 1 ton; alfalfa, 5 tons; timothy, 2 tons; clover, 5 tons; potatoes, 500 bushels; tomatoes, 5 tons; cabbage, 18 tons; turnips, heavy yield; watermelons, 175 dozen; all fruits yield well.

From different sources it is learned that three artesian-well bores have been made, two of which are entirely successful, having, it is stated, a 6-inch flow, and under such pressure as to be sufficient for the irrigation of 160 acres.

A large number of well bores have been contracted for in the Upper Moxee Valley, and one special enterprise on the high mesa land is looked forward to with great interest. For one of these wells $3,500 has been raised, so that the full limit of depth, flow, and pressure may be obtained.

The North Pacific Canal Company have completed 25 miles, and expect to finish 20 miles before the summer of 1892.

WYOMING.

As one of the northwestern groups of States, Wyoming forms part of the sources of the greatest river system on the continent. It lies between latitude 41 and 45 degrees north and longitude 104 and 110 degrees west. It is about 420 miles from east to west, and 300 miles from north to south. In area it is the fourth largest State in the Union, and contains 62,645,120 acres. On the north it is bounded by Montana; on the east, by South Dakota and Nebraska; on the west, by Idaho, and Montana; and on the south, by Colorado and Utah. It is divided by vast parallel chains, from which rise high peaks, culminating, in the case of the Laramie, at the height of 10,000 feet above sea level. Wyoming, topographically and hydrographically, is a great water-gathering area; remarkable alike for the extent of its high altitude precipitation, conveying great volumes of water through its river courses, and bearing remarkably striking relations in its eastern half to the climatology of the great plains region. The mean altitude is 6,450 feet. The main range of the Rocky Mountains extends across it southeast to northwest, entering Colorado along the one hundred and fifth meridian of longitude. The larger portion of the new State lies northeast of the continental divide. From the eastern border to the western slope of the continental range, Wyoming consists of a succession of parallel mountain ranges, separated by broad valleys and having the normal Rocky Mountain trend towards the northwest. The average elevation of the intra-mountain valleys ranges from 4,000 feet to 6,000 feet. The mountain ranges rise from 8,000 to 11,000 feet. The principal of these ranges are the Wind River Mountains, in the northwest, which is one of the sources of the Rio Colorado; the Black Hills, in the northeast; the Laramie Range, in the southwest; and further to the south the Medicine Bow Mountain, lying on the Colorado border and entering that State; further west and beyond the main Rockies are the Bishop Mountains; the Rattlesnake and Sweet Water Ranges in the central and western part of the State.

The Rattlesnake Hills are north of the Sweet Water, the mountains of the same name being pierced by the river. The culminating features of the topography of Wyoming, outside of its mountain peaks, are the Laramie Plains, which have a length, northwest by southeast, of 90 miles, and an average breadth of 75 miles, with an elevation of 7,000 feet, and embrace an area of 4,480,000 acres. The surface of this plateau varies in character and somewhat in elevation, a considerable portion of the area consisting of grassy plains, while another section is formed of ragged foothills with but little vegetation. The Black Hills, a large portion of which are in South Dakota, lie between the forty-third and forty-fifth parallels of latitude and the one hundred and third and one hundred and fifth meridians of longitude. They extend north and south about 100 miles, and average about 50 miles in breadth.

West of the Rocky Mountains the Green River section bears the characteristics of the basin region, of which Utah and Nevada form the principal political divisions. Hydrographically, it is the chief northern tributary of the Colorado River system. Topographically, it presents a broad series of table lands covered with sage brush (artemesia) and gramma grass. The Green River Valley is of a more arid character than the great mountain valleys that lie east of the continental range. This basin extends from latitude 43° southward to the Uinta Mountains in Utah, and from the Wind River ranges westward to that of Wyoming. Its area in Montana and Utah will embrace about 6,500,000 acres. The soil is of a gravelly, granitic character, and with the application of water will be found remarkably fertile, producing the temperate fruits and grain in abundance.

East of the continental divide, Wyoming is drained by large tributaries of the Missouri River. The Big Horn (which in its upper course is known as the Wind River), the Tongue, and Powder rivers also rise in the Rocky Mountain ranges and flow north and join the Yellowstone in Montana. These streams all have important tributaries. In the northeast the Little Missouri flow northward, passing through the southeast corner of Montana and joining the Missouri in South Dakota. Further south are a number of its forks. The Cheyenne River flows eastwardly into the Dakotas. The South Platte, still further south, rises in the northern part of Colorado and flows directly northward into Wyoming, where it receives the Medicine Bow River and the Sweet Water—one from the east and the other from the west—and then bends east and southeast, just below the center of the State, until it enters Nebraska, near the boundary of which it receives the Laramie River, with its tributary from the south and Raw Hide Creek from the north. In the southeast corner of the State several small streams rise and join the South Platte in Colorado. The high altitude at which all these streams rise insures their almost constant character. It indicates also the possibility of an enormous increase for economic purposes of the volume of water which, with melting snows and heavy rainfall, they will, under climatic conditions, carry direct to the main rivers and hence to the Gulf. The storage of torrential or storm waters and the recovery to the surface of a great percentage lost by rapid drainage and seepage into the earth will be found in Wyoming a task simple to competent engineering, the results of which will amply repay the efforts made. The surface supply furnishes water enough even now to irrigate from 18 to 20 per cent of its entire area. Appropriations have already been made from nearly 600 streams, and for farming and grazing purposes a large supply has been taken out by irrigation ditches. The water shed of Wyoming is equal to fully one-third of the entire State, that is, over 22,000,000 acres. The character of this hypsometric area may be better understood by the following table of altitude:

Area between—	Square miles.
3,000 and 4,000 feet	3,000
4,000 and 5,000 feet	19,000
5,000 and 6,000 feet	20,000
6,000 and 7,000 feet	24,000
7,000 and 8,000 feet	17,000
8,000 and 9,000 feet	7,200
9.000 and 10,000 feet	4,300
10,000 and 11,000 feet	2,300
11.000 and 12,000 feet	900
12,000 and 13,000 feet	100
Total	97,800

There are no large lakes, but many small ones, lying in the mountain regions. A majority of these are so situated as to be readily made serviceable for storage reservoirs. The Yellowstone, within the boundaries of the National Park, so named, is a fine sheet of water from 10 to 15 miles wide, 22 miles in length, and having a depth of 300 feet. Upon the divide, on either side of this lake, are many small lakes at from 10,000 to 11,000 feet above sea level. The majority of these small lakes have no outlets, showing that they are only storage places for drainage of the plateau region. Southwest of the Yellowstone Lake are found the Shoshong, Madison, and Lewis lakes, with others still smaller and mostly unnamed. The National Park, in the north corner of Wyoming, must prove in the development of irrigation hydrography one of the most fortunate acts of national legislation, reserving as it does to future industry those sources of a great drainage system flowing east and west that are found within its borders. For example, 12 miles south of the Yellowstone Lake lies one of the principal sources of the Snake River, known as Heart Lake.

Forty miles from the source of the Snake, Jackson's Lake is found, an irregular body of water 8 miles in length and from 2 to 3 miles wide with a depth of 250 feet. Some distance below, two other lakes about a mile apart are found. Still farther to the south are two bodies of water called Taggart and Phelps Lakes, which are nearly surrounded by moraines or glacial walls, having a height of 150 to 420 feet above the surface of the waters. In the Teton Mountains, at an altitude of 10,300 feet above sea level, a lake bed filled with solid ice has been found. Fremont Lake, 10 miles long and 2½ miles wide, lies about 12 miles from the southwest of Fremont Peak. In the Bear River region, near the source of Salt River, may be found a beautiful body of water called Alice Lake. There are a large number of such lakelets in Wyoming, a great many of which will yet be utilized in a storage system. The average annual temperature of the State reaches the mean of 44° The entire State lies on the isothermal line of 50°. In the mountain ranges the mean annual temperature will average as low as 36°, while eastward, on the plateaus and plains, its average is from 44° to 46°. The records at Cheyenne, covering for temperature a period of fifteen years, shows an annual mean of 43° 56′, a minimum of 25°, and a maximum of 90° 2′. The average of humidity would be about 54°. A notable fact is that the prevailing winds for eleven out of fifteen years have been from the north, during the other four they came from the west. This is of great importance in considering the channels of distribution or precipitation over the great plains.

West of the continental divide the valleys of the Big Horn, Sweet Water, and other Missouri River tributaries, form the chief arteries for distribution of such Pacific Ocean currents as they cross the Cascade and Upper Rocky Mountains on their way from the North Pacific. Their annual mean is a little higher. The greatest humidity in Wyoming, so far as rainfall is concerned, will be found in the four months of summer—that is, from May to August—when evaporation is also most rapid. Owing to the heavy snowfall the actual humidity of the atmosphere is greater from the middle of August to the middle of spring. The general climate is equable, high, dry, and quite mild. Though the temperature in midsummer will reach 90°, the nights are always cool. In midwinter, though it may fall below zero, the dryness of the air makes it far more endurable than the higher temperature along the humid Atlantic coast or in the great river valleys. It is very difficult to estimate or arrive at anything like a satisfactory conclusion as to the amount of water precipitated, in the form of snow, upon the mountain ranges of the State. State Engineer Mead considers it a fair estimate to state that the annual depth in water, chiefly of melted snow, must be between two and three feet, giving an approximate deposit of 60,000,000 acre-feet of water. Allowing for the disappearance of two-thirds of this supply by evaporation and phreatic processes, there will still be left 20,000,000 acre-feet of water to pass down the streams and be made valuable for irrigation purposes.

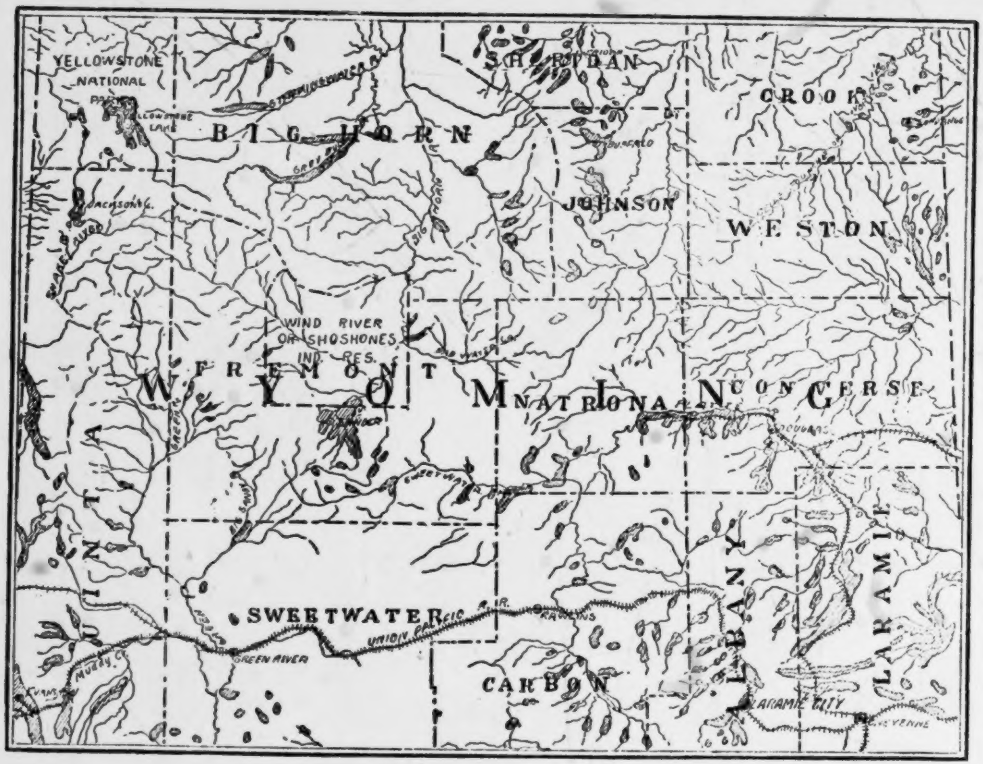
The forests of Wyoming, variously estimated at from 7,000,000 to 15,000,000 acres, can give, except at the sources of the streams, but a slight influence upon either the retention in the soil or distribution by channels, of the great precipitation that falls within this State. An estimate by counties, embracing also the Yellowstone Park, which is more heavily timbered than other sections, will give an area of 7,718,400 acres. The larger portion of the timbered area is confined to the mountain ranges, between 4,500 to 10,000 feet above sea level, and is formed on the eastern slopes of the continental range.

The surface of the valley, bench, and plateau lands of Wyoming is usually slightly rolling in character, quite free from stones, bowlders, or other obstructions, easily accessible, and readily broken to the plow. The valley soils are a black loam and red gypsum. The mesa or bench lands are largely of a rich, red, sandy loam. The great expanse of alkilized surface, covered only by sage brush and greasewood, can be made by irrigation among the most fertile of areas. The larger proportion of Wyoming will doubtless continue to be devoted to stock-raising. Its grasses are among the most succulent and valuable to be found in the region west of the one hundredth meridian. The climatic conditions and the distribution of its waters make exceedingly favorable conditions, not only for ranching on a large scale, but also for the breeding of and caring for fine cattle and horses. A large proportion of the extensive appropriation for water is now intended for use on the cattle ranches. As irrigation develops the water will be first applied to the cultivation of alfalfa and other forage crops, thereby increasing the capacity of the land for pastoral purposes, lessening in all probability the area of ranches and rapidly increasing the change already begun from cattle ranching to stock and breeding farms of a high character. A considerable proportion of the highest plateau region of Wyoming will raise, with the storage development and judicious distribution of water, large crops not of forage alone, but of the hardier grains, vegetables, and roots for the supply of both man and animal. In the eastern, and especially in the northeastern portion of the State, the agricultural area is already known to be extensive while new arable districts are constantly being brought to public notice.

This northeastern district, including Johnson, Sheridan, and Crook counties, is the best watered in State, all of the counties being supplied with mountain streams whose waters have great fertilizing qualities. Johnson County now consumes, it is claimed, one-fourth of its surface supply, and 64,000 acres are given as capable of easy irrigation. There were recorded 430 ditches in the county clerk's office in 1889, with a total length of 730 miles. The total capacity is stated at 9,117 cubic feet per second. The number of ditches already constructed in Johnson and the adjoining county of Sheridan will successfully irrigate, it is claimed, 450,000 acres. The products of these 3 counties include all the tame grasses and grains of the temperate region. Wheat and oats return 45 to 50 bushels per acre; potatoes, 200 bushels; onions, 300 to 500 bushels. The area embraced within the counties of Johnson, Sheridan, and Crook are watered by the tributaries of the Missouri River, which flow through them northward to that great channel. Carbon County, to the southward and center, with an area of 12,816 square miles, is another large farming region. Irrigation to insure crops is an absolute necessity. The county is watered by the Sweetwater and Platte Rivers. In 1889 21,000 acres were under fence, and during the succeeding year this area was increased by at least one-third. The whole of the Platte Valley within this county, from 10 to 30 miles wide, is available for agriculture, and readily yields large crops of the hardier cereals. Oats return 46 bushels, wheat 50, potatoes 3 tons, beets 4 tons, and hay 1,600 tons per acre. There are no large irrigation ditch systems in Carbon; appropriations of water are distributed through private ditches. Nearly all the land under fence is supplied by water from ditches. About 50,000 more acres can, it is claimed, be irrigated from the surface supply. Converse County, also part of the North Platte Basin, is devoted generally to stock-raising, but has about 8,000 acres under cultivation, 3,000 of which are irrigated. As elsewhere, the mesa or bench lands, when supplied with water, are found to be best for farming purposes. Without irrigation the small farms will give 30 to 40 bushels of wheat per acre; irrigated, the increase will be from 50 to 75 bushels per acre. Alfalfa produces 2 full crops per year. Albany County, which covers the high Laramie Plains, is found to be possessed of fertile soil, well adapted to temperate cereals and grasses, accessible to irrigation, and with water sufficient for two-thirds of the whole county. The mountain portion is heavily timbered, and root crops grow in great abundance. There are about 25 ditches, having a main length of 200 miles and in laterals nearly 1,000 miles. This system includes 6 small reservoirs. The cost has been about $250,000. The acreage served is over 100,000. The altitude ranges from 5,000 to 7,000 feet. Fremont County has also a considerable area cultivated, and claims one-half of its entire area as suitable for farming purposes, especially those acres that have been irrigated.

No failure of crops is known when the land is watered. These counties, with those of Uinta and Sweetwater, include nearly all the areas now cultivated within the State of Wyoming. It is claimed by the State engineer's office that at least 5,000,000 acres of land in Wyoming can be made productive by ordinary irrigation methods from the waters now in sight. This area, it is estimated, could easily be doubled by the construction of reservoirs for the storage of storm waters. No consideration has, as yet, been given to the supplies to be found below the surface, in the form of undersheet water in the great valleys, or of the underflow in the lower bench and prairie lands, formed from the drainage of the adjacent foothills and ranges. Artesian water, it is known, can be obtained in considerable quantities, but as yet it is not to be considered a source of supply for such economic purposes as irrigation. The soil, wherever irrigated, is found to be fertile and productive of all the hardier grains, vegetables, and fruits growing elsewhere in the temperate zone. The average yield of wheat will not be less than 25 bushels per acre; oats will produce 30 bushels. At $1 for wheat and 50 cents for oats, the value of such crops would not be less than $175,000,000. The yield per acre in potatoes will not be less than 150 bushels; while grass crops will produce from 5 to 6 tons per acre.

According to the State engineer's report for 1889, there were recorded over 2,600 ditches, drawing their supply from more than 400 different water courses. With irrigation scarcely established there is enough land under ditch and ready for the plow to make 80-acre farms to the number of 20,000. The best watered and most extensive agricultural districts are found in the central and northeastern portions of the Territory.



YELLOWSTONE NATIONAL PARK
YELLOWSTONE LAKE
BIG HORN
SHERIDAN
CROOK
JOHNSON
WESTON
WIND RIVER OR SHOSHONES IND. RES.
FREMONT
WYOMING
NATRONA
CONVERSE
BIG HORN R.
DOUGLAS
SWEETWATER
UNION PACIFIC R.R.
RAWLINS
GREEN RIVER
CARBON
ALBANY
LARAMIE
LARAMIE CITY
CHEYENNE
UINTA
MUDDY CR.
EVANSTON
BUFFALO
JACKSONS L.
SNAKE RIVER

IRRIGATION MAP OF WYOMING.

Shaded portions show districts now under ditch.

The number of recorded ditches is over 2,600, and there are more than 5,000 unrecorded. The total length of irrigating ditches is over 5,000 miles. Wyoming, then, is third in the total area of its irrigated land and second in the number and mileage of its irrigation canals. It must be remembered, however, that it is the largest for pastoral purposes and cultivation of forage. The following table was filed with the Senate Committee on Irrigation in 1889:

[Territorial engineer's report.]

Number of districts organized	9 *7
Total number of ditches recorded	2,438
Total mileage of ditches as reported	4,250
Acreage under water	1,946,875
Total capacity claimed in cubic feet of water	20,381,723

[According to the U. S. Geological Survey as presented by Director Powell.]

Acres under ditch constructed or projected	1,227,819
Acres irrigated or under water	500,000
Percentage actually irrigated	.08
Acres cultivated as per this ratio	40,000

The chief sources of this irrigation supply, as stated by counties, are as follows:

Counties.	Streams.
Albany	Big and Little Laramie, with their tributaries.
Carbon	Sweetwater and North Platte and branches.
Fremont	Green, Snake, Yellowstone, and Sweetwater rivers, the Big and Little Horn, Beaver, Gray, Bull, and other tributaries.
Converse	North Platte and Cheyenne Rivers, with numerous tributaries of both.
Crook	Powder, Little Missouri, Belle Fourche, Upper Cheyenne, Little Powder, and many tributaries; also Sand Creek, fed by large mountain springs.
Sheridan	Upper tributaries of the Tongue, Little Horn and Big Horn rivers.
Johnson	Powder River and its larger forks.
Uinta	Bear, Green, Salt, and Snake rivers, with forks and tributaries.
Sweetwater	Green River, Big and Little Sandy, and tributaries thereof.

The reservoir works so far constructed in Wyoming are designed entirely for general supply. The facts relating to them are as follows:

Location.	Source of water supply.	Capacity of reservoir.	Cost.
Cheyenne, Laramie County	Infiltration wells in bed rock of Crow Creek by gravity.	Dam and reservoir, 214,000,000 gallons.	$275,000
Laramie City, Albany County	Springs 2½ miles east of city.	Area of 5 acres	18,000
Rock Springs, Sweetwater County.	Green River	3,000,000 gallons	200,000
Sundance, Crook County	Springs, by gravity, to and from reservoir,	60,000 gallons	12,000

In addition to these works there are 18 artesian wells in the Territory, 16 of them being located at and near Laramie City, 1 at Cheyenne, and 1 at Rollins. The Laramie wells are from 130 to 150 feet deep. There are also a small number of bored wells in the neighborhood of Laramie, in which the water rises not quite to the surface and is raised by means of windmills. The water of these wells is used entirely for domestic and stock purposes. Prof. Bailey, who served as field geologist in the artesian wells investigation during the summer of 1890, for southeast Dakota and eastern Wyoming, finds all the con-

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*Unorganized. The largest portion of these acres is cultivated for forage, not grain or vegetables.

ditions necessary for a large artesian water basin. The report of the artesian wells investigation gives his observations and statements, which include sixty salt and gas wells, artesian in character. There is no doubt whatever that large supplies of phreatic waters may be obtained at small cost within the valleys and lower basin regions of Wyoming. The existence of seepage water on the lower portion of plains belonging to the Laramie Range has already been developed. The same formation, geologically speaking, exists in eastern Wyoming that is found in the western Dakotas and throughout western Nebraska, Kansas, and eastern Colorado. The average duty of water in Wyoming is estimated at one cubic foot per second during the irrigation season. The average expense of irrigating the land by the system of ditches now in vogue is about $10 per acre.

The unrecorded ditches are small farm trenches made by the plow as a usual thing. But very little corporation work has yet been done in the State. Combinations of farmers and ranchers have been made to construct ditches needed. Under the constitution of Wyoming the open waters of the State are declared to be public property, inalienable from the land, common in use for beneficial purposes, and subjected to the supervision of the State authorities. The management of the water supply and its distribution is intrusted to a State board of control, consisting of the State engineer and the superintendents of the water divisions. Under Territorial authority, their duties were imperfectly performed by the county clerk, district court, and Territorial engineer. The latter is now a State officer. This State board is a new feature in irrigation legislation, but its formation has met with marked approval throughout the arid region. Under laws brought over from the Territorial period, ditch owners are required to file in the office of the county clerk a statement showing the capacity of their ditches, location, and average water supply, with any other facts that may be called for to make a complete record. No penalty has been attached to this requirement, and as statistics show it has often been disobeyed. The hydrography of Wyoming is such as to form only four great divisions or drainage systems. These are now recognized in the State engineer's office. The first is a continuation of the North Platte and its tributaries. The Platte River is one of the most important water channels along the eastern slope of the Rocky Mountains. It rises on the western slope of Longs Peak, in Colorado, and drains an extensive area before entering Wyoming. Owing to its northern detour, it drains the waters of a large area within the borders of the new State, running a length from the Colorado border to that of Nebraska of 350 miles, the major portion of which is of such a character that the waters may be readily diverted to agricultural uses.

Division No. 2 embraces all of the streams east of the Big Horn Mountains, a region of fine farm region in the central, northern, and northeastern portions of the State. This division comprises, with others, the agricultural counties of Johnson and Sheridan.

Division No. 3 includes the Big Horn River and its tributaries. It drains a large proportion of both the Wind River and the Big Horn Mountains.

Division No. 4 is watered by the Green, Bear, and Snake rivers, with their tributaries lying to the west of the continental divide. In this division there is abundant opportunity for the construction, on a large or small scale, of a system of storage reservoirs and of canals and other works necessary for water supply and distribution. Very few prior appropriations have been recorded therein, and but little has been done in the direction of irrigation. The division has great opportunities and offers a large field for those interesed. Being free from legal disputes and largely unoccupied, it may easily be made the seat of a scientific yet simple system of irrigation works framed on a large scale, and therefore economic in character.

State Engineer Elwood Mead, under date of October 30, 1890, made to the governor a report on the condition of irrigation in Wyoming for the current year. The last Territorial legislature had failed to make an appropriation for the expenses of the engineer's office, and as a result its usefulness was largely curtailed. River gauging and similar work was, however, carried forward by local assistance. The most important station established was on Clear Creek, near Buffalo, Johnson County. This is the center of a large and important arable area, watered by numerous mountain streams. The lack of funds largely impeded the progress of field inquiries, and the engineer confined himself to a consideration of legal questions, water-right disputes, and the most obvious and equitable modes of settling them. As Engineer Mead presented to the Senate Committee on Irrigation a very full report of developments up to the close of 1889, there remained but little of actual work to chronicle.

The most important work has been in the western part of the State. Along the tributaries of the Green River considerable land has been reclaimed and construction begun on one large canal. In other parts of the State but little has been accomplished in the way of the building of new work, the tendency being to await further action by Congress in regard to the public land, and the enactment of the State laws controlling the public waters.

The year has been prosperous for completed irrigation works, as the water supply has been abundant in the western portion of the State. Elsewhere complaints have been few. Crops were generally excellent in yield and quality.

The report closes with suggestions as to the future work of the State board of control and of the State engineer's office.

Under date of December 31, 1891, Mr. P. L. Naismith, assistant State engineer, forwards, through the courtesy of Hon. F. E. Warren, United States Senator, the following statement:

Summary of irrigation development by districts.

I.

[State engineer's report for 1891.]

	Total number of recorded ditches.	Total lengths stated.	Total capacity as given. (In miner's inches.)	Total acreage watered as given.	Number of ditch claims, omitting statement of capacity.
		Miles.			
1*	643	1,322.4	5,911.6	482,434	48
2	327	582.8	6,649.8	379,165	53
3	282	317.4	3,644.1	395,563	72
4†	....	....	....	....	....
5	502	996.4	10,422.7	440,540	57
6	124	197.0	1,556.0	58,162	36
7	322	518.2	1,659.0	108,977	96
8	182	212.4	3,095.5	35,395	79
9	49	91.4	342.0	42,460	25
‡	7	11.9	136.8	4,180	....
Total	2,438	4,249.9	33,417.5	1,946,876	466

* Seven reservoirs additional.

† District No. 4 omitted because of incomplete record.

‡ Unorganised district.

II.

	To January 1, 1891.	During year of 1891.
Total number of ditches	3, 080	a 210
Total length of ditches, miles	5, 464	970
Total capacity, in cubic feet per second	2, 563, 900, 000	....
Total acreage under ditch	2, 172, 781	856, 700
Estimated cost of ditches per acre	$3. 02	....
Total cost of ditches	$7, 865, 467. 22	$3, 464, 260

a Applications.

In response to your inquiry as to the irrigation development of Wyoming, I would say that the law of 1886 required that a statement of claim as to the size, length, capacity, etc., of all the ditches built prior to that date be filed with the county clerks of the different counties, and that henceforth a statement of all proposed ditches be filed before the construction of the same is commenced. The new irrigation law, approved December 22, 1890, required that these records be transferred to the office of the State engineer, and that henceforth all ditch records be kept there. These are now at hand, and from them the inclosed table as to the irrigation development up to January 1, 1891, has been prepared. The tendency in most cases has been rather to overestimate than to underestimate the acreage under ditch, but from observations made by the engineer's department and the board of control during the past season it has been estimated that fully 15 per cent of the ditches have never been recorded, so that the acreage stated in the table can be taken as fairly approximately correct.

The new law requires that henceforth a permit be secured from the State engineer before the commencement of the construction of any ditch within the State. The application for this permit must state the proposed length of the ditch, its size, estimated cost, length, and a plat must be filed, showing its proposed location, together with the land proposed to be watered.

There have been filed in this office during the past year two hundred and ten applications, from which the inclosed table, as to the development during the past year, has been prepared. In addition to what is there stated, there was one application for a permit to divert the waters of the North Platte River within the State borders, but as the greater part of this proposed ditch is to be in Nebraska it has not been included. However, I might state that the proposed length is 275 miles, and that its estimated cost is $3,000,000.

It might be well to remark, however, that while undoubtedly the great majority of these ditches have already been built, or will be built within a reasonable time, there are some which represent opportunities, rather than actual ditches. Of the two hundred and ten applications, there are five the estimated cost of which is $2,750,000, which it is to safe to say will never be built unless the lands reclaimed can be made a basis to secure the money spent on their reclamation.

ANSWERS FROM CORRESPONDENTS.

The following data is compiled from answers to circulars received by this office:

CARBON COUNTY.

Saratoga (post-office), J. H. Mullison (October 1, 1891):

Water supply: North Platte River flows 2,772 feet per second at lowest stage.
Irrigation works: 25 miles, main ditches and laterals; 3 ditches—No. 1, 10 feet on bottom, 2 feet deep; No. 2, 12 feet on bottom, 2 feet deep; No. 3, 4 feet on bottom, 2 feet deep. Headgates 3; lateral gates, about 150.

Dams 3: No. 1, 150 feet long, 3 feet high; No. 2, 180 feet long, 5½ feet high; No. 3, 250 feet long, 2 feet high, reservoirs, 2.

Area under this system under ditch, 1,200 acres, under cultivation 1,000 acres. Total area irrigated and in crops in Carbon County, 39,869 acres; number of irrigators in county, 272.

Average cost per mile of ditches (this system), about $25 including laterals. Cost of reservoirs, $150 each.

Average cost per acre of works, ditches, etc, $2.50; annual maintenance and repairs per acre, about 25 cents; for preparing land for cultivation under irrigation, $10 per acre; for grazing, $2.50, per acre. Cost of water supply to user per acre, 25 cents.

Products under irrigation: Hay, grain, vegetables.
Estimated value of product per acre, about $15 (separate from grazing).
Estimated value of product per acre, for Carbon County, $6.83.

Saratoga (post-office), L. G. Davis (October, 1891): Saratoga Land and Irrigation Company:

Water supply: North Platte River.
Irrigation works: 14 miles main ditch, about 20 feet wide on bottom at head; average width 10 feet on bottom; about 15 miles of laterals; one main headgate, about 20 small ones for laterals; one dam 300 feet long, 20 feet wide; capacity of ditch at upper part, about 200 cubic feet per second.
Cost per mile of main ditch, an average of $750; cost of dam $1,000.
Average cost per acre for main ditch and laterals, about $2.
Average cost per acre for maintenance and repairs per annum, from 5 to 10 cents.
Average cost per acre for preparing land for cultivation through irrigation: $5 to clear, plow, and seed to oats or wheat sage-brush land.
Area under ditch, 8,000 acres; area under cultivation under this ditch, 3,000 acres.
Chief products under irrigation: Oats, wheat, and barley are principal cereals; alfalfa, timothy, and native grasses; potatoes and other vegetables.
Average yield of products per acre: Oats, 25 bushels; wheat, 20 bushels; barley, 25 bushels; potatoes, 400 bushels; alfalfa, 4 tons; timothy, 1½ tons; native hay, 1 ton.

Saratoga (post-office), Fred. Mathyas, C. E., (October, 1891):

Represents a company anticipating the construction of two systems of irrigation—first, to take water from Medicine Bow River, 650 cubic feet per second, to irrigate lands in townships 19 and 20, ranges 83 and 84; second, to take water from Brush, Barret, and French creeks, 400 cubic feet per second, to irrigate lands in townships 16, 17, and 18, range 83 west.
Works: Two main canals, 20 miles in length each—first, Medicine Bow Canal, 20 feet base at headgate, depth water 7 feet, slope 1 to 1; second, Brush Creek Canal, 18 feet base at headgate, depth water 4 feet, slope 1 to 1; 5 reservoirs located. Total area, 12,200 acres; largest dam to be 500 feet long, 62 feet high (rock).
Headgates and waste weirs: Medicine Bow Canal has 4 (also 14 drops, 6 feet each); Brush Canal, 5; headgates for laterals not planned yet.
Estimated cost of canals per mile: Average, $4,000; 5 reservoirs, $120,000.
Estimated cost of water to user per acre, $3.
Estimated area covered by these two systems, 120,000 acres and 90,000 acres.
Estimated area under ditch between mouth of Brush Creek and Fort Steele, along river, 6,000 acres; under cultivation, 1,200 acres.
Average cost per acre in neighborhood for preparing land for cultivation, $6 (sage brush).
Average cost per acre in neighborhood for farm or private ditches, about $2.50.
Average cost per acre in neighborhood for maintenance and repairs, 15 cents or less.
Products: Hay and pasture; yield of hay, 1 ton per acre.

Durbin (post-office), John Durbin (October, 1891):

Water supply: Muddy Creek, mountain stream; abundant supply in spring months.
Irrigation works: 2 miles of ditch, 4 feet on bottom; one headgate.
Area under ditch, 400 acres; under cultivation, 60 acres, and 100 acres of hay land.
Average cost per acre for preparing land for cultivation, $5 (sage-brush or greasewood land); cost per acre of main ditch, $1.50; cost for annual maintenance and repairs, very small.
Cost of water supply to user per acre, $1.50.
Chief products under irrigation: Hay, oats, and potatoes; yield of hay per acre, 1 ton.

CONVERSE COUNTY.

Douglas (post-office), secretary of Douglas Ditch Company and W. D. Pease, C. E. (September, 1891): Surveys for ditch made, plats completed, etc., but construction work not yet begun.

Water supply: North Platte River; supply unlimited.
Mileage and size of ditch: 40 miles; 15 feet wide at bottom, 22 feet at top; 1 headgate; no reservoirs; ditch cuts from river and reaches the surface within first mile.
Estimated cost per mile of ditch, $2,000 to $4,000; cost per acre, $7.
Average cost per acre for preparing land for cultivation, $3 to $10, including ditches.
Average cost per acre for annual maintenance and repairs, 25 cents to $1.
Area under ditch, 15,000 acres.

Chief products under irrigation: Alfalfa, wheat, oats, potatoes, and other vegetables.
Average value of products per acre, $35.
Average yield of products per acre: Hay, one-half to 1 ton; wheat, 30 to 40 bushels; oats, 70 to 80 bushels; potatoes, 200 bushels.

JOHNSON COUNTY.

Buffalo (post-office), Gustave E. A. Mohler (October, 1891).

[Data for county generally.]

Area under ditch, 250,000 acres; under cultivation, 116,544 acres.
Water supply: Big Horn River, Powder River, No Wood River, and the following creeks: Shell, Painted Rock, Medicine Lodge, Ten Sleep, Cañon, Deep, Kirby, Crooked, Crazy Woman, Clear, French, Rock, Johnson, Sayles, and Piney. All except the first-named river have their sources in the Big Horn Mountains.
Works, mileage, and size of ditches: 3,160 miles, varying from 16 feet on the bottom and 25 feet on top to 1 foot top and bottom; headgates, 420; no reservoirs.)
Cost per mile of ditches, from $30 to $1,200.
Cost per acre of water supply to user, from $1 to $5. (This has been about the cost per acre of works, ditches, etc., but ditches now taken out to reclaim land will cost more, as all land near water courses has already been taken up and reclaimed.)
Average cost per acre for annual maintenance and repairs, not over 25 cents.
Annual rental cost for water supply, from $1 to $1.65 per acre.
Chief products under irrigation: Oats, wheat, barley, potatoes, and hay.
Estimated value of products per acre: Grain, $35; potatoes, $75; hay, $25.

Trabing (post office), John R. Smith (October, 1891): Has 1,200 acres under (his own) ditch; under cultivation, 700 acres in grass, 90 acres in grain.
Water supply: Crazy Woman Creek, 6 feet of water.
Works: Ditch 6 miles, 7 feet on bottom, 9 feet on top; one reservoir; dam about 40 yards long; one main headgate; one waste gate; 80 or 100 lateral gates.
Cost per mile of works (ditch, dam, reservoir, and gates), $1,000; average cost per acre of works, ditches, etc., in vicinity, from $3 to $8.
Average cost per acre for preparing his own land for cultivation under irrigation (and cost of his land, etc.): Government land, $1.25 per acre; ditching, $5; grubbing sage brush, $2; plowing, $3.
Cost per acre for annual maintenance and repairs: About 25 cents.
Chief products under irrigation: Wheat, oats, rye, barley, alfalfa, blue-stem grass, timothy, clover; all kinds of garden products.
Average yield of products per acre: Wheat, oats, rye, and barley, from 35 to 40 bushels.

SHERIDAN COUNTY.

Sheridan (post-office), Simon J. Evans (October, 1891):
Works in progress: 8 miles of ditch, 5 feet on bottom, 600 feet tunnel in sandstone, 2-foot dams. Water supply not stated.
Cost per mile unknown; area under ditch not stated.
Average cost per acre for preparing land for cultivation under irrigation, $5 to $6.
Average cost per acre for irrigation works, ditches, etc., $10 to $20.
Average cost per acre for annual maintenance and repairs, $1 to $1.25.
Products: Wheat, oats barley, corn, alfalfa, timothy, clover, all kinds of vegetables and small fruits.
Average product per acre: Wheat 30 to 50 bushels, oats 40 to 60 bushels.

UINTA COUNTY.

Evanston (post-office), Wm. Hinton (October 1891):
Water supply: Bear River—"Bear River and Yellow Creek Canal" (system now under construction).
Works: Two and one-eighth miles main canal, 16 feet on bottom, 20 feet on top, 3 feet of water; grade, $5\frac{28}{100}$ feet per mile; laterals, about 40 miles; one main headgate in 3 sections (reservoirs contemplated).
Cost per mile for main ditch or canal, about $4,000.
Average cost per acre of irrigation works, ditches, etc., in neighborhood, about $4. (Lands near water courses have been irrigated at a cost not exceeding 50 cents per acre; expense will be greater hereafter.)

Average cost per acre for preparing land for cultivation under irrigation, $10 (including clearing and grubbing brush, plowing, leveling, and fencing).
Average cost per acre for annual maintenance and repairs, about 50 cents.
Area under ditch in Bear River Valley, 200,000 acres, one-half under cultivation.
Product: Principally hay crop, alfalfa, timothy, and native grasses.
Yield per acre, from 1 to 5 tons—2 tons a fair average.

CENSUS FIGURES.

The United States Census Office (Bulletin 107) reports for this State (Mr. F. H. Newell) as follows for the enumeration year 1889-90.

Number of counties	12
Number of irrigators	1,917
Total acreage irrigated and in crops	229,676
Average size of such farms	119
Average value of products per acre	$8.25

ON THE GREAT PLAINS.

The final reports of the field staff of the artesian and underflow investigation are a full presentation of the physical conditions of irrigation possibilities of the Great Plains region, rendering any further effort a work of superorogation. The following statements are, however, summarized from reports received in this office, and have value as a record of facts:

KANSAS.

Principal irrigation systems.

[J. W. Gregory, Garden City, Kans.]

Name of canal.	Name of owner.	Sources of water supply.
Eureka	W. Kans. Water Works and Irrigation Co.	Arkansas and underflow.
South Side	South Dodge Canal Co.	Underflow.
Garden City	Garden City Irrigation Co	Arkansas River.
Kansas	do	Do.
Southwestern	Southwestern Irrigation Co	Arkansas and underflow.
Western	Western Irrigation and Land Co	Do.
Amazon	Syndicate Lands and Irrigation Co	Do.
Alamo	Alamo Irrigation and Manufacturing Co.	Arkansas River.
Englewood	Claremont Land and Irrigation Co.	Cimarron River.
Emerson (1, 2, 3, and 4)	S. F. Irrigation and Improvement Co	S. F. Republican River.
Ward	Ward Irrigation Co.	Solomon River.

Location (counties).	Main canal.	Laterals.	Capital stock of company.	Amount now invested.	Acres irrigated.	Acres irrigable.
	Miles.	*Miles.*				
Gray, Ford, and Edwards	96	150	$1,000,000	$2,000,000	3,000	50,000
Ford	15	20	250,000	50,000	1,000	15,000
Finney	10	20	300,000	15,000	4,000	10,000
Do	20	30	....	35,000	8,000	20,000
Kearney and Finney	40	85	200,000	60,000	10,000	50,000
Do	25	40	250,000	200,000	5,000	25,000
Kearney, Finney, and Scott	99½	75	2,000,000	325,000	2,000	34,000
Hamilton	30	70	10,000	35,000	2,000	15,000
Clark	8	6	....	7,000	600	2,000
Cheyenne	70	25	100,000	150,000	....	35,000
Phillips	10	5	24,000	5,000	200	....
Total	423½	526	4,134,000	2,882,000	35,800	256,000

Mr. Gregory also gives the following list of organized companies:

The Des Moines and Western Irrigating and Land Company; Medicine Lodge, Barber county, capital stock $25,000.

The Consolidated Irrigation and Water Power Company, Dodge City, capital $1,000,000.

The Interstate Irrigation Company, Leoti, Wichita county, capitalized at $500,000.

The Smoky Hill River Irrigation Company, Russell Springs, Logan County, capital stock $1,000.

The Irrigation Land Company, Topeka, capital stock $251,000, to do business "in Colorado and surrounding States," with headquarters at Topeka, Kans., and at Las Animas, Colorado.

The Western Kansas Waterworks and Irrigation Company, Dodge City, capitalized at $2,000,000.

The Smith-Buck Irrigating Ditch Company, St. Francis, Cheyenne county, stocked at $5,000.

The Arkansas Valley Land and Irrigation Company, with headquarters at Vera, Waubaunsee County, capitalized at $1,000,000. The place chosen as the headquarters of this company is on the 96th meridian and outside even the semi-arid region.

The Northwestern Kansas Irrigation Company, of Colby, Thomas County, capital stock, $50,000.

The Union Pacific Canal and Land Company, Sharon Springs, Wallace County, capital stock, $300,000, proposes to construct dams for irrigation and water power.

The Kendall Irrigation and Manufacturing Company, Kendall, Hamilton County, stocked at $10,000; also the Kendall Canal Company, same location and same amount of capital stock.

The Greeley County Irrigation and Water Company, Tribune, capital $5,000.

The Lane County Irrigation Company, no place specified as headquarters, capitalized at $25,000.

The Beaver Irrigation Company, Leoti, Wichita County, capital $10,000, to take water from "Beaver and Ladder Creeks."

The Western Irrigation and Land Company, Topeka, capital stock $250,000.

The Arkalon Irrigation and Water Power Company, Arkalon, Seward County, capital stock $15,000; to take water from the Cimarron—depending largely upon underflow.

CHEYENNE COUNTY.

St. Francis (post-office), South Fork Irrigation and Improvement Company:

Water supply: South Fork Republican River.

Irrigation works: 143 miles of main canal and feeder, and other ditches nearly completed; main canal 70 miles long takes water 3 miles west of Kansas line, where it is 24 feet wide, 5½ feet deep, and terminates in a reservoir 4 miles south of St. Francis with capacity of 116,000,000 cubic feet, from which distributing ditches extend to lands of the main divide; capacity of canal, etc., 600 cubic feet per second; also works to develop the underflow and (under construction) a 20-mile ditch to irrigate the bottom lands above St. Francis, and supply that city for fire and other purposes.

Cost of works: $170,000 has been expended.

Area under this system, 50,000 acres.

Cost of water supply to user, $1,000 for a perpetual water right (1 cubic foot per second); maintenance and repairs, not large.

ELLIS COUNTY.

Ellis (post-office), W. F. King (September 22, 1891); Hays City (post-office), C. W. Miller (October 7, 1891):

One well (near a creek) 20 feet deep was pumped at the rate of 1,800 gallons per hour, without diminishing the supply; 4 or 5 acres irrigated by means of these wells. Last season rainfall was sufficient for crops. Water should be stored in reservoirs.

Very little irrigation in county; none from streams by dams or reservoirs; some small gardens are irrigated by means of surface wells 18 to 20 feet deep, mostly along streams; water being pumped by aid of windmills and others.

FINNEY COUNTY.

Garden City (post-office), C. A. Brown and James Craig (October and September, 1891):

Water supply: Arkansas River; area under ditch, 150,000 acres; under cultivation, 25,000 acres.

Works: 75 to 100 miles ditches; 20 feet bottom; 30 feet top; 3 feet deep; head gates, 4; no reservoirs.

Cost per mile of ditches, $200 to $500; laterals, $1.50; average cost per acre for ditches, etc., $1.35 to $3; annual maintenance and repairs, 25 cents to $1.50.

Average cost per acre for preparing land for cultivation under irrigation, $3.

Cost of water supply to user per acre, $1.25 to $2.

Area under ditch, 150,000 acres; under cultivation, 25,000 acres.

(Mr. Craig reports 21,000 acres under ditch; under cultivation, 7,000 acres.)

Staple products under irrigation: Wheat, oats, corn, barley, alfalfa, millet, sorghum, potatoes, cabbage, onions, fruit, grapes, berries.

Average yield per acre: Wheat, 15 bushels; oats, 40 bushels; corn, 30 bushels; barley, 35 bushels.

(Mr. Brown estimates the value of product per acre at $10 [for crops outside of forage]; forage, $25.)

GRAY COUNTY.

Ingalls (post-office), E. J. Clark, county register (September 29, 1891):

Water supply: Underflow of Arkansas River.

Irrigation works: 96 miles of ditch, 25 feet bottom, 40 feet top, 5 feet deep. Supply obtained by excavating ditches from 3 to 10 feet deep along side of the river; water obtained in quicksand below river bottom; fall of river, 7 feet per mile; 80 reservoirs from 2 to 50 feet deep; area, from 10 to 160 acres; one head gate; one waste gate 2 miles below mouth of underflow ditch.

Area under ditch, about 500,000 acres; under cultivation, 50,000 acres.

Cost per mile of works, ditches, etc.: Total cost, $700,000; average per mile, $7,291.64. (Greatest cost on first 30 miles, through hills, rock, blasting, etc.—on tableland cost was from $200 to $300 per mile.)

Average cost per acre for preparing land for cultivation under irrigation: Breaking, $2; fencing, $1.50; small lateral ditches, 25 cents; total, $3.75.

Cost per acre for maintenance and repairs: Only expense a "ditch walker" for each 8 miles, at $1.50 per day.

Cost of water supply to user per acre, $2; annual rental cost, $2.

Products: Wheat, rye, oats, barley, corn, alfalfa, potatoes, cabbage, and other vegetables and breadstuffs; orchards under irrigation quantity and quality of fruits equal to those of California.

Average yield of products per acre: Wheat and rye, 40 to 50 bushels; oats, 80 to 120 bushels; corn, 65 to 100 bushels; barley, 80 to 140 bushels; potatoes, 300 to 500 bushels; alfalfa, three crops per year, 2 tons per acre. (Sweet potatoes, pumpkins, squashes, and melons do well without irrigation.) For grazing, 3 acres under irrigation are equal to 10 acres without.

Without irrigation the yield is: Wheat, 8 to 15 bushels; rye, 12 to 18 bushels; oats 20 to 30 bushels; corn, up to 20 bushels; barley, 10 to 25 bushels; Irish potatoes are a failure three out of four years; alfalfa from one-half to three-fourths ton per acre in a moderately rainy season; dry season, none.

MARION COUNTY.

Peabody (post-office), W. H. Morgan (October, 1891):

Rainfall in Marion County has been a good average for twenty years, but farmers should build small dams across small "draws" for watering stock—not necessary for irrigation. County well watered by streams, and well water is obtained at a depth of from 10 to 60 feet, ample for all purposes, including irrigation on a small scale by windmill power.

M'PHERSON COUNTY.

McPherson (post-office), A. F. Waugh (October 7, 1891):

Irrigation very little practiced; some gardens irrigated by water from wells—raised by windmills many seasons like the present when rainfall is sufficient.

MEADE COUNTY.

Meade (post-office), A. H. Heber (September 17, 1891):

Only two farms in the county irrigated through artesian wells cultivating about 100 acres.

NORTON COUNTY.

Norton (post-office), F. M. Lockard (for William H. Stiles) (September, 1891):

This county is in the semiarid region, but has no system of irrigation; irrigation very much needed; want all the help to aid in getting irrigation under way.

PAWNEE COUNTY.

Larned (post-office), George W. Watson, superintendent (September, 1891):

Have built no works; simply have the right under our charter; farming our lands in wheat and seldom need irrigation; 6,000 acres under cultivation.

KEARNEY COUNTY.

H. H. Filley, C. E. (Kansas City, Mo.), engineer Southwest Kansas Land and Irrigation Company (October 6, 1891):

Water supply, Arkansas River.
Total mileage of main and lateral ditches, $122\frac{8}{10}$ miles; depth, 4 feet 9 inches; width, 16 feet bottom, 31 feet top, gradually decreasing to about 11 by 4 feet at end of lateral; surveys made for two storage reservoirs, aggregating 1,800 acres; number of head gates, 1 set, 8 gates; 1 aqueduct or flume (timber).
Cost of works: Partially constructed by a former company and no record of cost preserved.
Area under ditch, 60,000 to 100,000 acres; under cultivation, 3,000 to 5,000 acres.
Cost of water supply to user per acre, $2.
[Works have been in operation too short a time to give much practical data.]

Lakin (post-office), C. H. Longstreth, superintendent Western Irrigation and Land Company (September 12, 1891):

Water supply: Arkansas River; also underflow supply.
Works: 75 miles main and lateral ditches; main ditch, 25 miles long, 20 feet at bottom; one set of head gates 40 feet wide at head of main ditch; no reservoirs.
Area under ditch, 20,000 acres; under cultivation, about 4,500 acres.
Cost per mile: Main ditch, $1,500; laterals, $15 to $20.
Average cost per acre of ditches, not exceeding $5.
Average cost per acre for preparing land for cultivation under irrigation, $3 to $5.
Average cost per acre for annual maintenance and repairs, 50 cents.
Cost of water supply to user per acre, $1.50; annual rental cost, $1.50.
Staple products: Alfalfa, wheat, oats, barley, vegetables, apples, plums, pears, peaches, apricots, berries, and small fruits.

KEARNEY AND FINNEY COUNTIES.

Edward Russell (Lawrence, Kans.) (September 2, 1891): Formerly interested in irrigation works in these countties.

Average cost per acre for preparing land for cultivation under irrigation along the Arkansas River in those counties, from $2.50 to $3.
Average cost for annual maintenance and repairs, from $3,000 to $5,000 (aside from salaries of officials). "This amount would be increased if the acreage taking water was materially increased; an increase of 1,000 acres would not increase cost of maintenance and repairs, but an increase of 3,000 acres would increase the cost probably $500."
Staple products under irrigation: Alfalfa, millet, oats, barley, wheat, and corn, and sorghum is also raised, potatoes (Irish and sweet), and other vegetables, also fruits.
Average ordinary yield per acre under irrigation: Oats, 50 bushels; wheat, 25 bushels; corn, 35 bushels.

RAWLINS COUNTY.

Atwood (post-office), A. M. Wilson and Albert Hemming (October, 1891):

"Mostly subirrigation in county; supply from underflow wells and surface streams; farmers dam up the numerous streams and 'draws;' about fifteen reservoirs and dams in county, with areas of about 10 acres each; cost of works about $100 each dam; area under ditch, about 3,000 acres; cost of water supply to user per acre $2.50."
Average cost per acre for preparing land for cultivation, about $5.
Average cost per acre for works, $2.50; maintenance and repairs, 50 cents.
Products: Wheat, oats, corn, rye, barley, flax, alfalfa, potatoes, and other vegetables
Yield of product: "Three times as much as without irrigation."

WILSON COUNTY.

Fredonia (post-office), T. Holdren (October 7, 1891):

"Beginning irrigation with windmill pump and tanks; too early to give data."

SEWARD COUNTY.

Arkalon (post-office), L. A. Etzold and T. A. Scates, secretary Arkalon Irrigation and Water Power Company (September, 1891):

"No system of irrigation in county at present in operation; nine miles of ditch to be constructed in the spring."

NEBRASKA.

CHEYENNE COUNTY.

Bayard (post-office), Thomas Winter, treasurer "Bayard Irrigation Canal and Water Power Company" (October 28, 1891):

Water supply: North Platte River (unlimited).
Irrigation works: 57 miles ditches; lower ditch 12 miles long, 15 feet at top, 10 feet at bottom; upper ditch, 45 miles; 45 foot top, 40 foot bottom; 2 headgates, no reservoirs.
Average cost per mile, about $2,000.
Area under ditch, 40,000 acres.
Area under cultivation, about 2,000 acres.
Cost of water supply to user per acre, $5.00 (perpetual water-right).
Annual rental cost per acre, $1.50.

DAWES COUNTY.

Crawford (post-office), Mr. Grubble (banker), October, 1891:
Water supply: White River, 20 cubic feet per second.
Works: Ditch not yet constructed.

Marshland (post-office), L. Snow (September 23, 1891):
Marshland Irrigation Company.
Works: Survey for ditch (22 miles) completed. Ditch to be completed within the next year.

DEUEL COUNTY.

Big Spring (post-office), John H. Abbot (September, 1891):
Water supply: (1) From streams and creeks emptying into North Platte River from the north; (2) from the North and South Platte rivers; (3) from underflow of these rivers; (4) by pumping from wells dug on the banks of the rivers.
Mileage or size of ditches, etc., not given.
Area under ditch, about 20,000 acres; under cultivation, 2,000 acres.
Not more than 1 per cent of cultivated land is under irrigation.
Average cost per acre for ditches, etc.: On bottom lands, from $1 to $2 (from underflow of South Platte River); ditches taken from small streams and creeks cost more.
Cost per acre for annual maintenance and repairs "would be small after the first few years."
No reservoirs of large size constructed. Headgates very crude.
Several steam pumps are used, which irrigate from 60 to 200 acres.
Cost of steam pumps and ditches to irrigate 160 acres, about $1,200.
Products: Wheat, rye, barley, corn, oats, potatoes, and garden truck.
["Irrigation would add tenfold at least to the product of our lands per acre."]

DUNDY COUNTY.

Benkleman (post-office), L. Morse, president "Dundy County Irrigation Company" (September 28, 1891):

Water supply: Republican River (underflow and surface water sufficient for all land that can be reached at reasonable cost).
Area under ditch, 5,000 acres; under cultivation, 1,000 acres (including meadows).
Irrigation works: 11 miles of ditch completed, 12 feet on bottom, 20 feet on top; earth banks; 1 reservoir, area 25 acres; practically no dam; 1 headgate; 3 flumes; 4 waste gates.

Cost per mile of main ditch, $350; average cost per acre, irrigation works, ditches, etc., $5; annual maintenance and repairs per acre, not to exceed 50 cents.
Staple products: Hay, alfalfa, wheat, oats, corn, potatoes.

["Ditch just completed, and only lands easily watered will be cultivated for the next year; no water rented, ditch owned by consumers."]

HITCHCOCK COUNTY.

Culbertson (post-office), W. D. Wildman (September 24, 1891):
Water supply: Frenchman River and Stinking Water Creek (about 310 cubic feet for second; annual rainfall, an average of 18 inches.)
Irrigation works: Ten miles of ditch completed; will be 70 miles long when finished (earth work, with wooden flumes); will be several reservoirs; one at Culbertson covers 10 acres; average depth, 10 feet; 2 headgates.
Cost per mile of works, $5,000 (about); average cost per acre, about $5.
Cost of water supply to user per acre, $10 (estimated for perpetual water-right).
Annual rental, cost per acre, $1.
Area under ditch, 100,000 acres; under cultivation, 25,000 acres.
Staple products: Wheat, rye, oats, vegetables of all kinds grown in this latitude; yield of wheat per acre, 40 bushels ($24).

KEITH COUNTY.

Ogalalla (post-office), C. A. Walker, engineer "Ogalalla Land and Cattle Company" (September 23, 1891):
Water supply: White Tail Creek (40 cubic feet per second).
Works: Being constructed, 6.8 miles ditch; 6 feet on bottom; 11 feet on top; one headgate.
Cost per mile, $300; area under ditch when completed, 6,000 acres; under cultivation, 500 acres.
Average cost per acre of ditches constructed in vicinity, 40 cents to $1.

[Ditches in neighborhood have been constructed within the last two years; were not used the past year, rainfall sufficient; works too new for other reliable data asked for.]

LINCOLN COUNTY.

T. B. Sweet, of Topeka, Kans. (September 12, 1891), president of company taking water from North Platte River, in Lincoln County:
Works: 25 miles ditch; top, 15 to 20 feet; bottom, 10 to 12 feet; no reservoir; wing dam, 200 feet; one headgate; fall of 9 feet 8 miles from headgate, with numerous checks.
Cost per mile of ditch, $3,000 (estimated); headgate, $5,000; dam, $3,000.
Average cost per acre of works, ditches, etc., $2.50 to $5.
Average cost per acre for preparing land for cultivation under irrigation, $3.
Average cost per acre for maintenance and repairs, 15 to 25 cents.
Cost of water supply to user per acre, $10 (for permanent water-right;
Area under ditch, 25,600 acres; under cultivation (exclusive of hay), 5,000 acres; 1,200 acres without irrigation.
Products: Wheat, oats, rye, corn, barley, potatoes.
Average yield per acre: Wheat, 25 bushels; oats, 40 bushels; rye, 35 bushels; corn, 60 bushels; barley, 40 bushels; potatoes, 150 bushels; native hay, 2 tons; very little grazing.

SCOTTS BLUFF COUNTY.

Gering (post-office), Isaac Simonson (September, 1891):
Water supply: Platte River.
Works: Ditch 22 miles long, 16 feet on bottom, 20 feet on top, 2 feet deep on grade; 5 headgates.
Area under their ditch, 50,000 acres; under cultivation, 9,000 acres (nearly). Three other ditches in county, with average of 30,000 acres covered by each.
Average cost per acre for preparing land for cultivation under irrigation, from $3 to $5; for annual maintenance and repairs of ditches, etc., 30 cents (on their ditch).
Average cost per acre for works, ditches, etc.: About $9 for ditches that irrigate only valley lands; for ditches to irrigate the table or high lands, cost is more than double.

Products: Wheat, oats, barley, rye, potatoes and other vegetables, clover, and grass. "The yield is great, but market value small."

Gering (post-office), "Farmers' Canal Company" (September 23, 1891):
Water supply: North Platte River, 700 cubic feet per second.
Works: 66 miles canal and laterals, from 30 to 6 feet on bottom; slope, 1 to 1; 5 headgates.
Cost per mile of ditches, $1,200; cost per acre, $6 to $10.
Average cost per acre for preparing land for cultivation under irrigation, $2 to $2.50; for grazing, $1.
Average cost per acre for annual maintenance and repairs, 25 to 50 cents.
Cost of water supply to user per acre, $8; annual rental cost, $1.
Area under ditch, 12,000 acres; under cultivation, 6,000 acres.
Products: Wheat, oats, barley, corn, flax, potatoes, onions, and other vegetables.
Estimated average value of crop per acre, $10.

Minatare (post-office), George W. Fairfield, secretary "Minatare Canal and Irrigation Company" (September 18, 1891):
Water supply: North Platte River; appropriation, 500 cubic feet per second.
Works: Twenty-one miles of canal at present (being extended), 40 feet on bottom; slope, 1 to 1; fall, 4½ feet per mile (slope of the valley); bottom of canal at head, 3 feet below river bed; one main headgate (5,000 feet of lumber used in it.)
Cost per mile of canal, etc., about $1,200; average cost per acre, about $4; cost per acre for annual maintenance and repairs, about 15 or 20 cents.
Average cost per acre for preparing land for cultivation under irrigation, $2.50 (breaking only necessary).
Area under canal at present, about 16,000 acres; under cultivation (and hay lands), about 4,000 acres.
Products: Wheat, oats, rye, barley, corn, millet, alfalfa, clover, blue grass, some timothy, potatoes, and other vegetables; also fruits and grapes.
Average yield per acre: Wheat, 30 bushels; oats, 60 bushels; rye, 25 bushels; barley, 35 bushels; corn, 60 bushels; potatoes, 60 to 100 bushels.

SHERMAN COUNTY.

Denver (post-office), C. W. Andrade (December, 1891):
Loup City (Nebraska) Canal, Water Power and Improvement Company; supply, Middle Loup River (Nebraska); 14 miles of ditch, 10 feet bottom, slope ¼ to 1; 3 headgates under construction; also has a reservoir of 90 acres; dam 922 feet long (earth), 165 feet wide at bottom, 30 feet at top, 40 feet high.
Area under ditch, 416,000 acres.
Area under cultivation, just beginning under ditch.
Average cost per mile, $7. Cost of reservoir at Loup City, Nebr., $25,000 (estimated).
Average cost per acre of canals, about $8 (for first-class canals).
Average cost per acre for annual maintenance and repairs, 15 to 60 cents (on our canals about 15 cents).
Average cost per acre for preparing land for cultivation under irrigation, about $2.
Cost of water supply to user per acre, $10. Annual rental cost, $1.75.
Products: Wheat, oats, rye, barley, corn, alfalfa, and potatoes. Sugar beets yield largely.
Average yield of products per acre: Wheat, 30 bushels; oats, 50 bushels; rye and barley, 30 to 40 bushels; corn, 60 bushels; alfalfa, 4 tons.

NORTH DAKOTA.

DICKEY COUNTY.

Ellendale (post-office), M. F. Merchant, chairman Dickey County Irrigation Committee (September 29, 1891):
Water supply: From Ellendale city artesian well.
Has 40 acres under ditch; 13 acres under cultivation past season.
Irrigation works: About 1¼ miles main ditch; 2½ feet top; 1½ feet bottom. One reservoir covering ¾ of an acre, with dam about 8 rods long, 2½ feet high. One head gate.
Cost of ditch per mile, about $25; cost of dam, etc., $5.
Average cost per acre for irrigation works, ditches, etc., under artesian system, about $2 (including main ditch and reservoir).
Cost per acre for annual maintenance and repairs, not to exceed 50 cents.
Cost per acre for preparing his land for cultivation by irrigation, about $3.
Products: His land planted to cabbage, onions, and other vegetables.
Value of product per acre: Cabbage, $250; onions, $300 (cabbage at 5 cents per head; onions, 75 cents per bushel).

SOUTH DAKOTA.

BEADLE COUNTY.

Huron (post-office), L. H. Hole. (September 24, 1891):

Water supply: Artesian well.

One hundred acres irrigated.

Mode of service; The waste water from a 75-barrel flouring mill, run by water power from an artesian well, with pressure of about 175 pounds to square inch, through 1 mile of ditch; four headgates for changing course of water; no reservoirs, dams, or other works.

First cost for completing ditch $75; cost for annual maintenance and repairs, about 10 cents per acre.

Average cost per acre for preparing prairie land for cultivation under irrigation $3; no grazing lands under irrigation.

Cost of water supply to user, per acre, $1.

Staple products under irrigation: Wheat, oats, corn, potatoes, and flax.

Average yield per acre: Wheat, 40 bushels; oats, 80 bushels; corn, 75 bushels; flax, 16 bushels (potatoes not yet harvested). No grass or hay.

BROWN COUNTY.

S. W. Narregang (Aberdeen post-office, September 12, 1891), and J. H. Fletcher (Santa Clara post-office, September, 1891):

Water supply: Artesian wells, average depth, 1,000 feet.

Area under ditch in county 10,000 acres (for 1892); cultivated, 2,000 acres.

Irrigation works: Reservoir for each well with areas of from 3 to 5 acres; small ditches, 3 feet on bottom, 8 feet on top, and laterals 1 foot for distribution; also surface wells and windmills to small extent.

Service: A reservoir with area of 3 acres, irrigates about 100 acres; a 5-acre reservoir will irrigate about 160 acres.

Cost of works: Ditches, $50 to $100 per mile; reservoirs, 5 acres, $300 to $400; reservoirs 3 acres, up to $300.

Cost of water supply to user per acre, $1; annual rental, $1.50.

Average cost per acre for preparing land for cultivation by irrigation, $1.50 (plowing).

Average cost per acre of irrigation works: Cost of water, ditches, reservoirs, laterals, etc., estimated at $8 per acre.

Average cost per acre for annual maintenance and repairs, about 50 cents.

Products under irrigation: Wheat, oats, barley, corn, millet, flax, potatoes, and other root crops; sugar beets will be extensively raised. Field of wheat (hard), 30 bushels.

[One artesian well near Aberdeen irrigates 640 acres; four more now being sunk within 2 miles will irrigate 2,000 acres.]

McPHERSON COUNTY.

Leola (post-office), Ira D. Clark (September 26, 1891):

Water supply: Springs about 1½ miles from his farm, "Also the water from the melted snow on an area of 7,000 acres, coming out of a gulch at the springs."

Area under ditch, 640 acres; under cultivation, 200 acres.

Works: About 2 miles of ditch, 3 feet on bottom, 4 to 5 feet on top; average depth, 1 foot; deepest cut, 2½ feet. One reservoir, area 3 acres; 2 sluices; no dam; 2 head gates.

(There are 2 main ditches, one running east and west through the section of land, the other north and south. Works laid out by a United States surveyor; not yet completed.)

Cost per mile of ditches, about $100; cost of reservoirs, etc., about $200; cost of all works for the 640 acres, estimated by surveyor at about $400.

PENNINGTON COUNTY.

Farmingdale (post-office), Charles Hamm (September, 1891):

Water supply: Rapid Creek; heads in Black Hills; capacity, 2,500 miner's inches; fall, 12 feet per mile.

Area under ditch, 1,500 acres; under cultivation, 1,500 acres.

Irrigation works: 10 miles ditch, 4 feet on bottom, 6 feet on top, 2 feet deep; dam, 3 feet high (cottonwood log tied and filled back with gravel); 3 head gates, besides waste gates.

Cost of works, $500 per mile; average cost per acre, $3.33.

Average cost per acre for preparing land for cultivation under irrigation, $4 (breaking prairie land).

Average cost for annual maintenance and repairs, 10 cents per acre (where owners of land make their own ditches); about $200 per year for works above named.

Products: Hay, oats, and corn (mostly hay).

Yield per acre: Timothy and clover, 3 tons; native hay, 1 ton.

Rapid City (post-office), Henry Behrent (September, 1891):

Water supply: Spring Creek; limited supply; can only irrigate certain time in the spring.

Area under ditch, 400 acres; under cultivation, 55 acres (40 acres on farm of Mr. B.)

Works: Three miles ditch, 3½ feet wide, 1 foot deep (300 feet of ditch 6 feet deep). Dam, 45 feet long, 18 feet high, 50 feet wide at bottom; one reservoir formed by original channel of creek, from 35 to 50 feet wide; water backs up over one quarter of a mile; also 150-foot plank flume 40 inches wide, 16 inches deep, with truss across creek channel; one open-box head gate.

Cost of ditch per mile, about $75; cost of dam, flume, etc., $600.

[This ditch, dam and flume, etc., was completed in July, 1891. Water not yet in use.]

Rapid City (post-office), Chris. Thomson (September, 1891):

Has a ditch (to irrigate his nursery) taken out of a creek (on his own land), that was supplied with water for twelve years, this year it dried up for the first time. Ditch and flume 1 mile long; ditch 4 feet on top, 2½ feet on bottom; dam 4 feet high.

Area under ditch, 120 acres; under cultivation, 115 acres.

Cost of ditch, flume, etc, about $500.

Average cost per acre in vicinity for preparing land for cultivation under irrigation, $4 to $5.

Average cost per acre for irrigation works, ditches, etc.: Large ditches from $2 to $3; small ditches, $4 to $6.

Cost per acre for annual maintenance and repairs, 25 to 50 cents.

Staple products under irrigation: Wheat, oats and hay.

Average yield per acre: Wheat, 35 bushels; oats, 60 bushels; hay, 3 to 6 tons.

SPINK COUNTY.

Mellette (post-office), J. P. Day (September 22, 1891):

Water supply of locality: Dakota Artesian Basin; wells at depth of 900 to 1,000 feet; Pressure about 150 pounds per inch (closed), 97 pounds with 2-inch opening; water soft and apparently wholesome.

Reports a well 1,000 feet deep, 8-inch casing, 6-inch pipe; about 3 miles of ditches (to be extended to 5 or 6 miles); ditches supplied direct from wells; ditches of various sizes. Preparing to use well for power for machinery, but will not interfere with irrigation.

Cost of well, $3,000; cost of ditches per mile, $100 to $300.

Cost of water supply to user per acre, $2.

Area under ditch, about 400 acres; under cultivation, 300 acres.

Mellette (post-office), William Bird (September 22, 1891):

Water supply: 4½-inch artesian well (owns one-third interest therein).

Works: 2 miles ditch, 16 feet wide at top (in the clear); banks 2 feet high. One reservoir with area of 4½ acres; banks 4 feet high; 3 feet wide on top. One headgate.

Area under ditch and under cultivation, 160 acres.

Cost of well, $815.

Cost per mile of ditches, $50.

Cost of reservoir, etc, $250.

TEXAS.

MARTIN COUNTY.

Marienfeld (now "Stanton") post-office, Dr. L. H. Moller, Joseph Gittinger, and J. B. Koutz (September, 1891):

No surface streams in vicinity. Water supply from wells from 20 to 135 feet deep, by means of windmills and pumps. Irrigation confined mainly to small orchards, vineyards, and truck gardens. Area under cultivation not extensive at present.

Cost per acre for preparing land for cultivation under irrigation about $3.